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A Key to Differentiate Nymphal Stages of Melanoplus Differentialis (Thomas) from Those of Melanoplus Bivittatus (Say), (Orthoptera); also, Descriptions of Instars and a Key for Identification of Nymphal Stages of these Two Species

Gerald Bishop Spawn

A KEY TO DIFFERENTIATE NYMPHAL STAGES OF MELANOPLUS DIFFERENTIALIS (THOMAS) FROM THOSE OF MELANOPLUS BIVITTATUS (SAY), (ORTHOPTERA); ALSO, DESCRIPTIONS OF INSTARS AND A KEY FOR IDENTIFICATION OF NYMPHAL STAGES OF THESE TWO SPECIES

By

Gerald Bishop Spawn

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INTRODUCTION

During the past few years South Dakota and neighboring states have been confronted with serious outbreaks of locusts. Whole crops of small grain and corn have been destroyed by the voracious insect hordes which at times left only bare ground where once had stood waving fields of grain.

Chief among the aggressors have been the two species, Melanoplus differentialis (Thomas), the Differential Locust, and Melanoplus bivittatus (Say), the Two-Striped Locust. The contents of this paper include studies of these two species only.

It is of considerable importance to the economic entomologist to know at the outset of his control campaign the species of insect with which he must contend.

There have been thus far, to my knowledge, no studies conducted by means of which was attempted the formulation of a key for the differentiation of nymphs of these two species. Neither have there been written any descriptions of the various nymphal instars of the two species in question, nor keys by means of which the nymphs can be placed in their respective instars. However, Mr. R. L. Shotwell (6)* has published a bulletin dealing with Melanoplus atlanis (Riley), the Lesser Migratory Locust, in which were discussed several of the points brought out in the present paper for M. differentialis and M. bivittatus.

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*Arabic numerals in parentheses refer to entries listed under literature consulted.

It may be generally stated, and rightfully so, that Melanoplus bivittatus hatches, on the average, about two weeks earlier than Melanoplus differentialis. This in itself, however, seems hardly a satisfactory criterion upon which the entomologist may base his conclusions as to the species with which he is dealing.

It is to be remembered that this paper is concerned with only two species of locusts. There are other harmful grasshoppers which hatch just as early as M. bivittatus or perhaps even earlier. The writer has reference here to large numbers of adult M. packardii Scudder in and adjoining Sully County, South Dakota, in late June of 1932 while there were yet very few adult bivittatus.

In the keys and discussions which follow, it must be borne in mind that references to size are all based on data concerning insects reared in the laboratory. It is quite probable that under outdoor conditions, which are undoubtedly more near the optimum for grasshoppers, the individuals will grow somewhat larger than they will when they are confined and grown under laboratory conditions. However, it is the writer's firm belief that the limits set forth in the following pages will hold true for by far the large majority of specimens.

METHODS EMPLOYED IN SECURING DATA

In the study of the immature stages of the grasshoppers the following method was used:

During the fall in which the work was started adult grasshoppers were caught and confined in pint Mason jars which contained about three inches of clean, damp sand. To provide air for the hoppers, the tops were cut out of the jar covers and fine mesh screen soldered into them. The insects were fed alfalfa and white clover leaves. The adults were caught rather late in the season and consequently did not lay many masses of eggs. When the adults died the sand was taken from the jars and the egg-pods were stored in a refrigerator until needed. Eggs were also collected from the field and stored in a refrigerator.

When the eggs were needed they were taken from cold storage and kept in covered glasses of moist earth at room temperature until they hatched, a temperature which ranged usually from 70° F. to 80° F.

Upon hatching the young hoppers were isolated in pint Mason jars as described above. The jars contained two to three inches of clean, slightly moist sand. A number was assigned to each nymph and a sticker bearing the number was pasted on the jar. The hoppers were numbered consecutively as they hatched. Corresponding numbers were assigned to the pages of a loose-leaf notebook. The date of hatching of each hopper was recorded on the sheet bearing the hopper's number. The jars were inspected

every day for molted skins and when these were found the date of molting was recorded. Notes were taken from time to time as the nymphs molted and grew.

Two different methods were used to anaesthesize the hoppers in order that descriptions, measurements and drawings of them might be made. In the first method the hoppers were put in the refrigerator and kept there until they became so cold that they could not move. This method served to keep them motionless long enough to describe and measure them, but they came out of the effects of the cold before they could be drawn.

The other method tried was that of confining the hoppers in a cyanide jar until all movements ceased. This method proved somewhat the better for keeping the hoppers motionless for drawing. If they are not left in the cyanide too long, they will recover and go on developing normally. However, recovery is sometimes slow, the insects showing effects of the poison even into the next instar and possibly beyond. Many of the hoppers were put in cyanide and killed outright before being studied.

In rearing the hoppers, several kinds of food were tried. Some were started on young wheat and later fed fresh lettuce. Others were fed entirely on fresh lettuce. Still others were started on head lettuce, later being fed alfalfa, white clover, dandelion leaves and leaves of wandering Jew or tradescantia. The feeding of the last mentioned food resulted in a higher mortality than usual, but the hoppers seemed to thrive on all

the other foods. They were fed and watered once a day and the jars were cleaned often enough to keep molds from growing on the body wastes and small bits of vegetation. The presence of molds in the jars increased the mortality considerably.

The eggs for the second generation of hoppers were collected by the same method as was used the first year. Methods of rearing and recording of notes were also as described above.

When the last of the hoppers were killed and the notes completed the data were assimilated and the general descriptions were written.

METHODS OF ILLUSTRATING

The illustrations thruout this work are photographs of camera lucida drawings or of actual parts of specimens. The drawings are all original.

In preparing the drawings different methods of shading were tried and in some cases only line drawings were used. Some of the drawings were shaded on one side of a median line with merely line sketches on the other half, while others were entirely shaded. Of all the different types of drawings used, it is the writer's opinion that line drawings are sufficient to show structural characters with drawings shaded on one-half to show color markings where bilateral symmetry is shown. If the figures show lateral views of surfaces the entire shading method is more important, that is, if the color markings are at all important, as in the case of the femora.

GENERAL DISCUSSION

Thruout the following pages the reader will probably notice that no mention is made concerning the phenomena of hatching of the nymphs. A discussion of the process of hatching is outside the limits of the present work. However, the author wishes to make himself clearly understood in his use of the term "intermediate molt." At the time of hatching the entire body of the nymph is enveloped by a thin, white membrane. This membrane remains on the body while the nymph is making its way thru the soil from the egg-pod to the surface of the ground. When the hopper reaches the surface this membrane is shed. It is the shedding of this particular membrane which is referred to as the intermediate molt or intermediate ecdysis. For various reasons the use of the term molt, for this process, seems entirely justified (7, p.42).

Another term, the definition of which might profitably be set forth at this time, is the word instar. An instar is the period of time elapsing between any two succeeding ecdyces or molts, for example, between the intermediate molt and the first molt, between the first and second molts, etc.

The word nymph has been very freely used. A nymph is generally understood to be an immature form of an insect having incomplete or direct metamorphosis.

Thruout the following discussions the descriptions apply to average individuals, as they were produced under laboratory conditions. There will be found occasionally an individual

specimen which varies perhaps considerably from the average in certain of the characters. This is to be expected inasmuch as there will at times be specimens showing natural variations from the average in any group of closely related animals.

Variations in size and development of specimens reared in cages in the laboratory may possibly be due to unnatural conditions of feeding, lack of preferred foods, lack of exercise and sunlight, etc. Excess or lack of moisture may also cause variation from the average. Differences in size between males and females of the species are established facts. It is the writer's opinion that differences in color are largely problems of inheritance, altho environment may also have its bearing upon these characters.

Other points which might well be taken up under the heading of General Discussion are to be found under headings to which they more specifically apply.

POINTS TO BE CONSIDERED IN DIFFERENTIATING BETWEEN NYMPHS OF M. DIFFERENTIALIS AND M. BIVITTATUS

In a discussion of this sort it may be well to first eliminate those characters which are of little or no consequence with regards to separating the nymphs.

Size of the nymphs, as a characteristic, may be discarded without any hesitation for reasons discussed elsewhere.

Structurally the nymphs of the two species are so nearly alike that so far as is known at present their separation

(except males of the sixth instar) cannot be based on morphological characters. Males of the sixth instar can be separated by means of the external genitalia or even by the cerci alone.

For immediate identification of the nymphs as a group, then, we must base our conclusions on color characteristics.

In a general way it may be stated that the nymphs of M. differentialis are darker than those of M. bivittatus, although there are occasional exceptions. M. differentialis is usually considerably more heavily mottled than M. bivittatus, which occasionally is almost entirely free from dark markings, except on the wing pads and hind femora.

The yellowish background color is, as a rule, noticeably brighter in the case of M. bivittatus. Quite often the nymphs of M. bivittatus beyond the second or third instar are green marked with black rather than the usual yellowish background with fuscous markings. The writer has never observed a nymph of M. differentialis with a green background color. Green nymphs, then, if belonging to either of these two species, are M. bivittatus. On the other hand, quite a percentage of specimens of M. differentialis exhibit melanism in varying degrees, from only slightly darker than usual to almost entirely black. However, even in the darkest individuals the markings of the hind femora are typical of the species as compared to M. bivittatus, and the light areas usually stand out very plainly against the dark background. A specimen of M. bivittatus exhibiting melanism has never been observed by the writer.

In both species there is a yellowish lateral thoracic stripe, wider at the anterior end, which extends from the front to the hind margin of the pronotum (Plates 6, 10, 12, 13, 18, 29). In M. bivittatus the stripe stands out clearly, bordered sharply above by brownish black to black. The lower margin of the stripe blends into the brownish black mottling of the lateral lobes of the pronotum. In some individuals the blackish markings are lacking. The stripe is usually narrower in the case of M. differentialis and is often slightly mottled instead of clear yellowish (Plates 12, 13, 18). The upper margin is not so clearly defined as in M. bivittatus. Occasionally the stripe does not reach the hind margin of the pronotum in M. differentialis.

The median carina of the thorax stands out definitely in both cases; however, in M. bivittatus the area on either side of the carina is considerably less mottled than is the case in M. differentialis, in which the mottling persists to the base of the keel. Consequently there is a much wider yellowish dorsal stripe in M. bivittatus.

Of the various color characteristics discussed those of the hind femora are the most important from our point of view. The outer face of the femur has a "herring-bone" weave appearance or the appearance of "chevrons". In this work these structures will be referred to as the "chevrons". Dorsally the femur is divided by a longitudinal keel into two regions which have been called the outer and inner faces of the upperparts. It is on the markings of the chevrons and the

outer face of the upperparts that the separation of the two species is largely based.

Melanoplus bivittatus has chevrons with the upper half to three-fourths solid fuscous to black with the possible exception of the extreme upper ends of the proximal two or three chevrons and fine lines separating the first five or six (Plate 1). The outer face of the upperparts is either

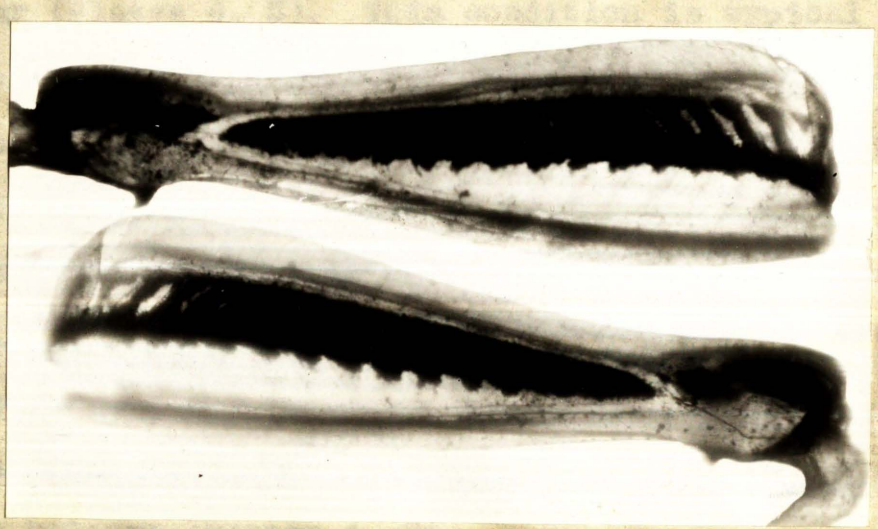

Plate 1. Hind femora of fourth exuvium of M. bivittatus.

clear yellowish to green or lightly sprinkled with fine brownish dots. Rarely three very faint darker areas are present on the outer face. These darker areas are very distinct over the inner face. The lower part of the chevrons are yellowish or yellowish-white to green and the exceptions mentioned are of the same color.

Melanoplus differentialis usually has the fuscous of the chevrons broken by alternating light areas (Plates 4, 5). The lower part of the chevrons, as in bivittatus, is usually clear yellowish to yellowish-white, as are the light areas of the dorsal halves. The outer face of the upperparts has three distinct dark areas separated by lighter areas which correspond in position with the light areas of the chevrons, thus giving somewhat of a transversely banded appearance to the femur (Plates 4, 5). This condition is typical of M. differentialis although occasionally a specimen is found in which the chevron markings are practically identical with those of M. bivittatus, at least so much so that they might be confused with regards to this one character. However, in these cases the dark areas of the outer face of the upperparts always come to the rescue by showing up very plainly, so that there need be no question as to the species to which the specimen belongs (Plates 4, 24).

A KEY FOR THE SEPARATION OF GRASSHOPPER NYMPHS OF THE SPECIES MELANOPLUS DIFFERENTIALIS AND M. BIVITTATUS

A. "Chevrons" of femur with upperparts running together to form solid fuscous, longitudinal stripe. Upper ends of proximal "chevrons" or fine lines separating them may be yellowish to green (Plates 1, 2, 3, 24) ---------- usually bivittatus.

B. Upper outer parts of femora, above "chevrons", of clear yellowish to green or possibly showing three very faint darker areas (Plates 1, 2, 3) ---- bivittatus.

B.B. Upper outer parts of femora, above "chevrons", definitely showing three darker areas alternating with light areas (Plates 4, 24) --- differentialis.

A.A. "Chevrons" of femur with upperparts not running together but broken by light areas (Plate 5). In the adult stage chevrons may extend clear across outer face of femur; dark and light areas alternating. Outer face of upperparts with three distinct dark areas --- differentialis.

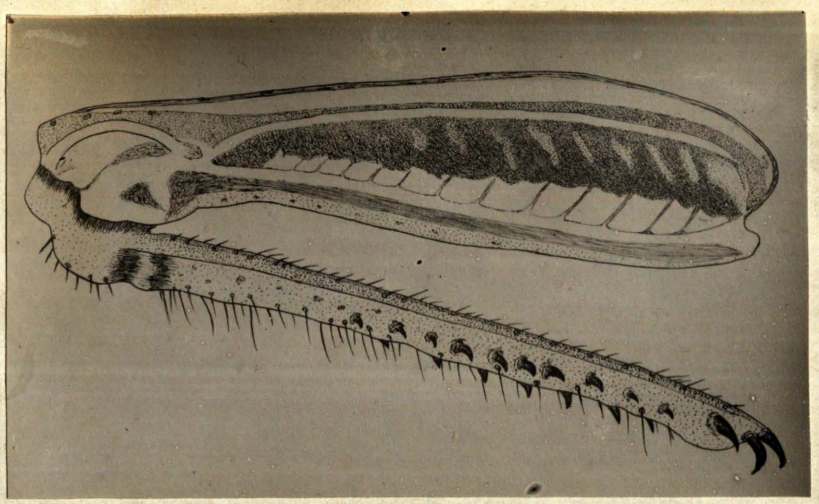

Plate 2. Hind femur and tibia of third instar of M. bivittatus

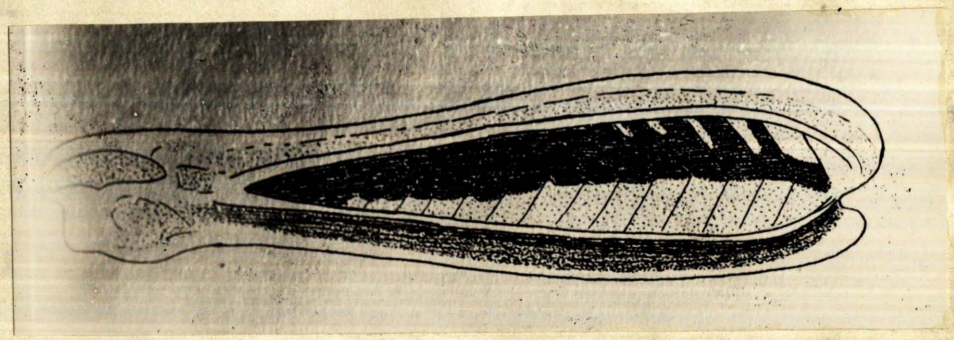

Plate 3. Hind femur of third instar M. bivittatus

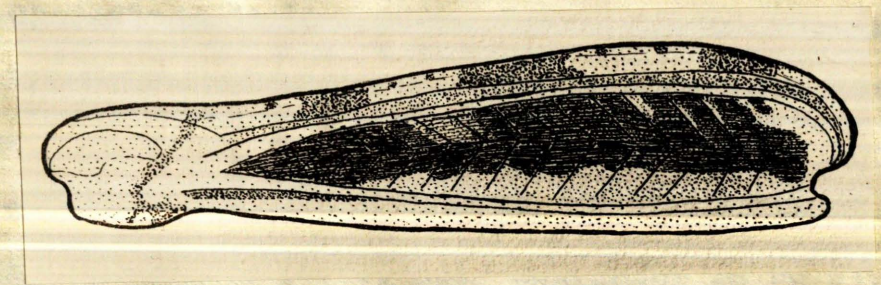

Plate 4. Hind femur of third instar M. differentialis

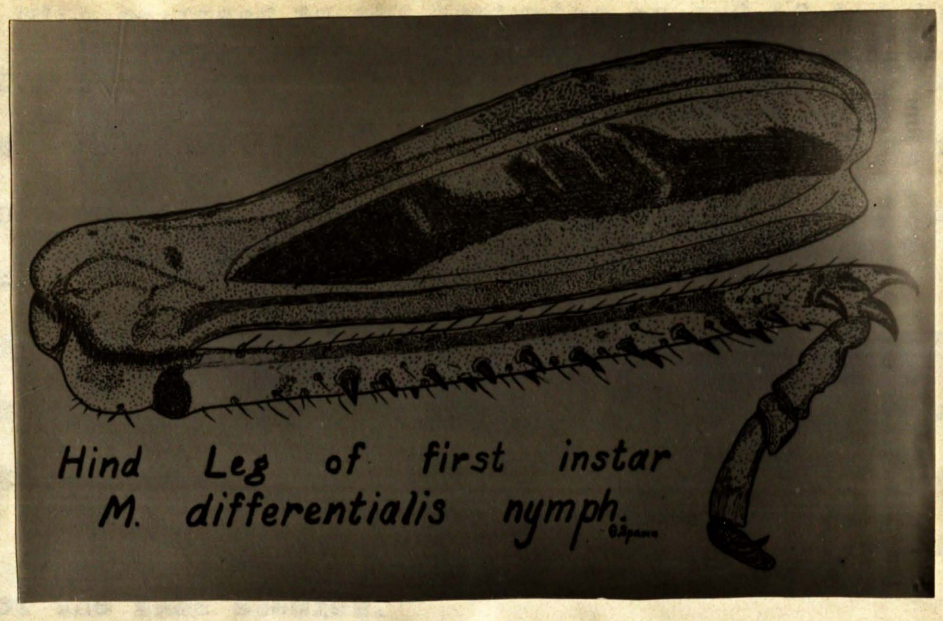

Plate 5.

POINTS TO BE CONSIDERED IN DETERMING THE INSTARS

For the purpose of separating grasshopper nymphs into their various instars there are certain characters which are of utmost importance while others are practically useless.

All characters dealing with size are more or less variable and are dependent to a very considerable extent on the conditions under which the hoppers are raised and on the kind and amount of food received.

Length of body is a very poor character to be given much weight in determining the instar to which a nymph belongs. The body length is directly dependent on the amount of food in the food tube. This character also varies to a large

extent with nearness to the beginning or end of the instar. The bodies of hoppers which are just ready to molt are extremely elongated and distended. The membranous areas between the chitinized rings of the segments are stretched to the utmost at this time. On the other hand, a hopper which has just molted is somewhat longer than it will be a few hours after molting and after the chitin becomes hardened, but not so long as it will be near the end of the instar. There is also a very marked difference of size between males and females of the same species.

Color characteristics are obviously useless as there is very little if any change in the markings of the nymphs from one instar to the next. There is more or less of a decided change between the last nymphal instar and the adult, but the presence of much more reliable characters definitely rules out the use of color markings.

Somewhat more on the borderline between poor and good characteristics for use in determining instars is the length of the hind femora. The length of each caudal femur is a much more reliable character to use than is the length of the body inasmuch as there is little opportunity for the femur to become extended longitudinally. However, it is the author's opinion that the femora do become slightly extended longitudinally as each instar progresses, which, if true, would detract from the value of this character. It seems that the length of the hind femur might be used much more accurately for the first two or three instars than it could for later stages. The

growth of the femur is dependent on the same factors that influence true general body growth.

Another character which might be used advantageously but which was not employed to any appreciable extent in this work, is the length of the keel or median carina of the pronotum. This character probably would be no more valuable, however, than the length of the caudal femora as both are dependent upon the same factors for their growth. To the writer it seems more logical to use the pronotal keel as more or less of a measuring stick for the wing pads because in this way we are dealing with two variable characters on the same individual and if one is larger, the others should also be larger. In other words, if we have two individuals of unequal sizes yet in the same instar, the length of the wing pads, (from the apex to the anterior point of the base), in relation to the length of the median carina of the pronotum should be proportionately about equal. This method is utilized only in the last two nymphal instars, that is, when the wing pads are turned upward.

Presence or absence of wing pads can obviously be used only in the earliest stages. On this point the author disagrees with Carothers (2, p.17-18), who claims that the wing pads in the first instar hoppers are easily discernable, and that the venation is already indicated. She also states that "even when hatched, both tegmina and wings are entirely free from the mesothorax and metathorax except at the joints."

The writer has found that the lower margins of the mesonotum and metanotum are free from the body but, to a certain extent, so is the lower margin of the pronotum. However, the genera worked with, in the two cases, were entirely different and this fact may explain the differences of opinion. Shotwell (6) considers the wing pads of the first two instars to be indistinct tho he does not state that they are indistinguishable. In the present work the author considers the wing pads to be indistinguishable up to the point where they cease to appear merely as the edges of their respective notal sclerites and begin to expand downward and backward and to show evidence of venation (Plates 9, 18).

Shape and position of wing pads can be used from the third instar to the adult stage as a rather reliable character. A more complete discussion of this character will be found in the description of the instars.

The number of antennal segments is a very reliable character in the earlier stages, the number for each instar being rather constant up to and including the fourth instar (Plates 7, 8). Beyond the fourth instar this character is not so reliable but nevertheless should be considered. Here again the author finds himself in disagreement with Carothers (2, p.16) when she states that the "antennae ... form new segments at the free ends, during the early instars." In the present study it was found that the increase in number of antennal segments does not occur only at the free ends, certain of the segments toward the middle of the antennae divid-

ing and forming two segments from what was formerly one (Plates 7, 8). Again, however, this may be due to the different genera studied.

Lastly the development of the external genitalia is more or less characteristic of the specific instars. These characters are especially useful in the first two or three stages. However, the characters which apply to both males and females of a species are the more desirable for use in a key, consequently these characters have been omitted from the key and are found only in the descriptions of the instars.

KEY TO THE INSTARS

Except Extra Instar

A. Wings not fully developed but in form of pads; pads of wings overlapping those of tegmina.

Immature Forms or Nymphs

B. Wing pads not distinguishable; lateral margins of mesonotum and metanotum rounded (Plate 6).

C. Antennal segments 12 to 13, approximately 95% of individuals with 13 (Plate 7). Length of hind femora 2.3 - 2.8 mm., majority 2.5 to 2.7.

First Instar

C.C. Antennal segments 15 to 17, approximately 90% of individuals with 17 (Plate 7). Length of

hind femora 3.1 to 3.9 mm., majority 3.3 to 3.7 mm.

Second Instar

B.B. Wing pads distinct; lateral margins of mesonotum and metanotum becoming roundly pointed.

C. Wing pads pointing downward and backward. Pads of tegmina overlapping those of wings.

D. Antennal segments 19 to 20, approximately 95% of individuals with 20 (Plate 8, A,B,C). Length of hind femora 4.7 - 6.6 mm., majority 4.7 - 5.4 mm. Expansion of wing pads slightly discernable (Plates 9,A,B and 18).

Third Instar

D.D. Antennal segments 22 - 23 (Plate 8, D,E). Length of hind femora 6.7 - 8.0 mm., majority 6.7 to 7.5 mm. Expansion of wing pads easily discernable (Plate 9, C,D).

Fourth Instar

C.C. Wing pads turned upward. Pads of wings overlapping those of tegmina.

D. Length of wing pads (apex to anterior point of base) 1/2 to 3/5 the length of the median carina of the pronotum (Plates 10, 11). Antennal segments 23 to 26,

majority with 24 or 25. Length of hind femora 7.0 - 10.7 mm., majority 8.2 - 10.2 mm.

Fifth Instar

D.D. Length of wing pads (apex to anterior point of base) as long as or slightly longer than median carina of pronotum (Plates 12, 13, 39, 41). Antennal segments 25 to 27. Length of hind femora 10.8 - 13.5 mm.

Sixth Instar

A.A. Wings fully developed, the ends of the wings approximating the tip of the abdomen. Tegmina covering wings.

Adults

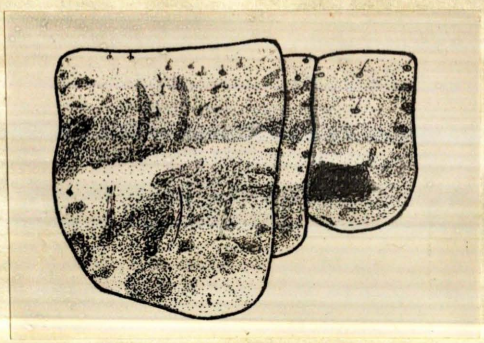

Plate 6. Pronotum, mesonotum and metanotum of first instar M. bivittatus.

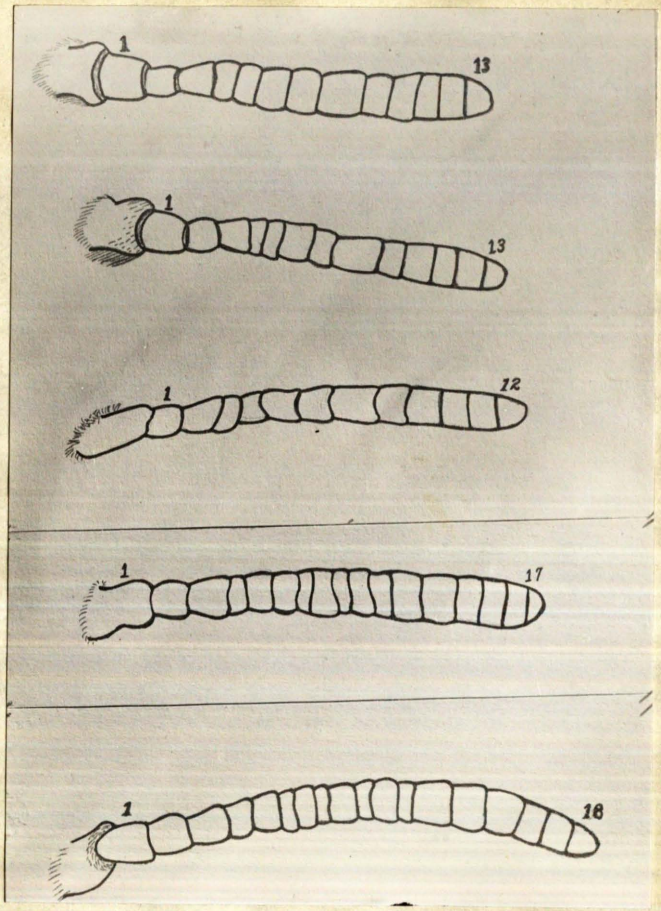

Plate 7. Upper three figures antennae of first instar nymphs.
Lower two figures antennae of second instar nymphs.

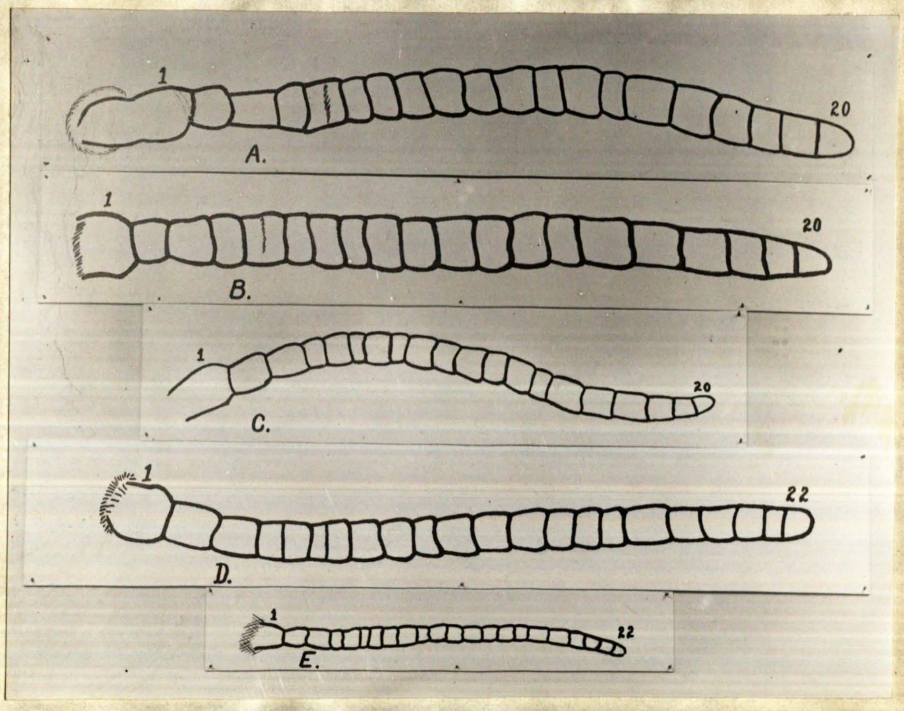

Plate 8. A,B,C, antennae of third instar M. bivittatus.
D,E, antennae of fourth instar M. bivittatus.

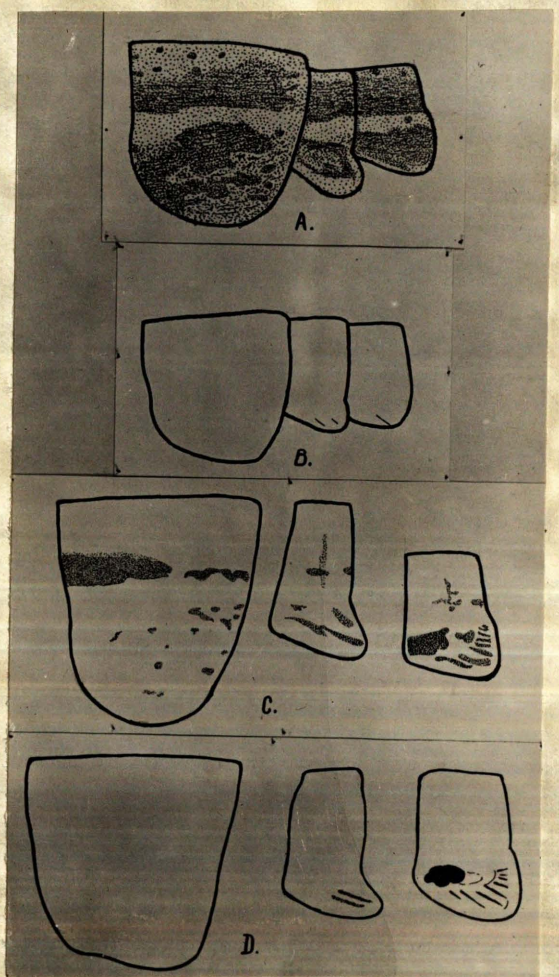

Plate 9. A, third instar M. bivittatus male; B, third instar M. bivittatus female; C,D, fourth instar M. bivittatus females.

Plate 10. Pronotum, tegmina and wing pads of fifth exuvium or molted skin of M. bivittatus male.

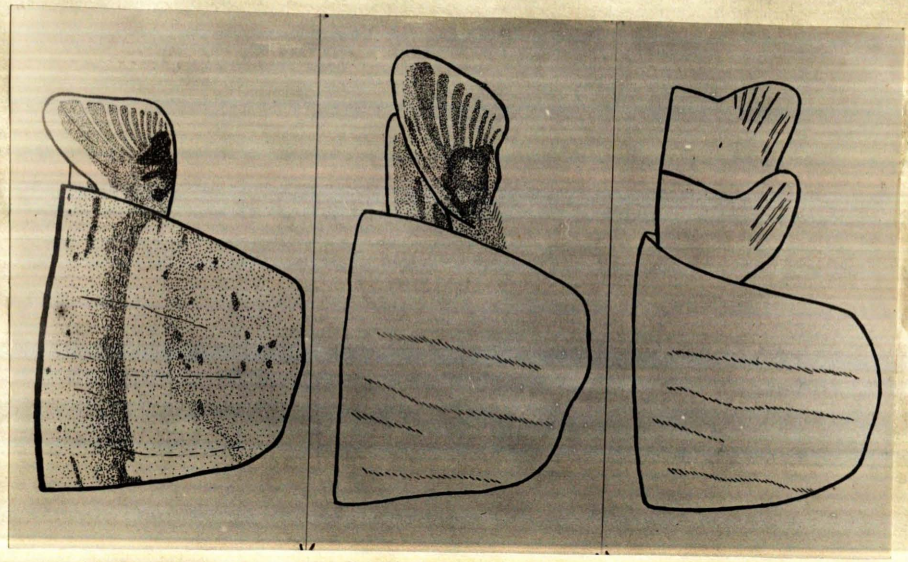

Plate 11. Top and center, pronotum and wing pads of fifth instar M. bivittatms males; bottom, fifth instar M. bivittatus female, probably would have been a 7-instar hopper.

Plate 12. Pronotum, tegmina and wing pads of a sixth instar M. differential male. Contrast with plate 13 in amount of dark color present.

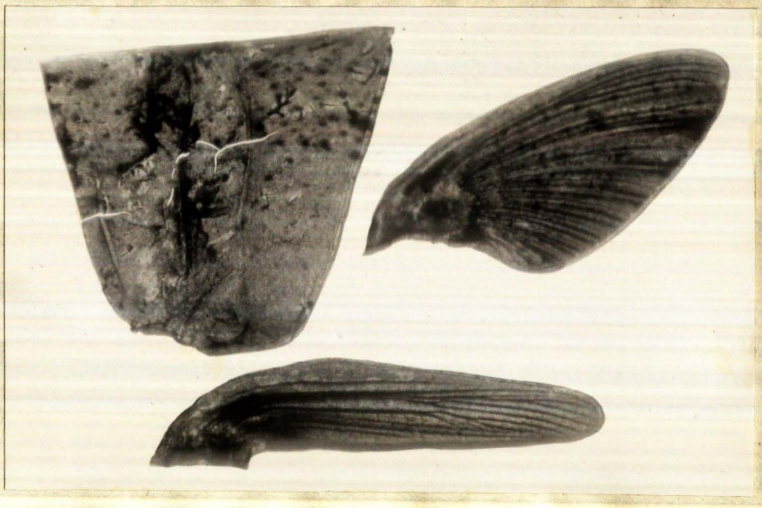

Plate 13. Pronotum, tegmina and wing pads of a sixth instar M. differentialis male. Contrast with plate 12 in amount of dark color present.

DESCRIPTIONS OF INSTARS OF M. DIFFERENTIALIS

First Instar M. differentialis

Length of Body - 4.5 to 6.0 mm., depending on degree of distension of body and nearness to beginning or end of instar.

General Coloration - Background color yellowish-white heavily mottled and tinged with brownish-black to black. Melanistic individuals may grade from this color to almost entirely black with characteristic light markings.

Head - Median dorsal line light colored; not raised. Shaded areas extend out transversely from the line in such a way as to form more or less of an "occiputal triangle", with the vertex between the eyes and the base along the back of the head. A narrow yellow strip extends from the upper margin of the eye to the back of the head. This is bounded ventrally by a fuscous stripe. From the posterior end of this stripe another yellowish stripe extends forward along the side of the triangle to its vertex. The margin of the eye is somewhat shaded, thus the last mentioned stripe is bounded on both sides by darker areas. The cheeks are heavily mottled with brownish-black. The frontal costa is concave. Antennal segments 12 to 13, majority 13 (Plate 7).

Thorax -

Prothorax - Median carina very sharp; knife-like; light colored. The disk of the pronotum is mottled to the immediate

base of the carina. Lateral carinae absent. There is a tendency toward the formation of a yellowish lateral line. The line seldom if ever reaches both anterior and posterior margins of the pronotum. It is usually present as a small yellowish patch, slightly longer than wide, about in the center of the lobes of the pronotum. The remainder of the pronotum is quite heavily mottled and tinged with fuscous.

Mesothorax and Metathorax - Median carina distinct; not so sharp as that of pronotum; light colored. Wing pads not discernable as such,* (Plate 6). There is very little of the background color on these two segments as a rule. However, occasionally a very light colored individual may be found. On the metathorax, at a point which will later be the base of the wing pad, there is a small subrectangular dark area (Plates 6, 9, 18). The first and second pairs of legs may be heavily or only slightly mottled above; quite clear below.

Hind Femur - Length, 2.3 to 2.8 mm.; majority 2.5 to 2.7 mm. Outer face of upperparts, above chevrons, with three distinct brownish-black areas alternating with areas of almost clear background color (Plates 4,5,24). The outer face of the underparts is usually brownish-black but may be any gradation from fuscous to clear background color. Chevrons with upper one-half to three-fifths not solid fuscous, but broken by light areas which alternate with the light areas of

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*Of the large number examined only one or two seemed to show the areas of the wing pads more or less distinctly by a line across the notal processes. However, there were no backward expansions on the sides of either mesonotum or metanotum.

the outer face of the upperparts (Plate 5). Rarely the light areas of the upper halves of the chevrons may be quite heavily tinged with dark, even so much so that they may be unnoticed except by careful observation. In these cases, however, the dark areas of the outer face of the upperparts always show very plainly (Plate 4). The lower two-fifths to one-half of the chevrons is of the clear background color.

The tibia has a dark basal band immediately followed by a light band (Plate 5).

Abdomen - Median carina distinct and light colored, extending to the posterior end of the abdomen, carina sometimes raised, depending on whether the individual is near the beginning or end of the instar. Mottling light to quite heavy; the dark dots tending to form longitudinal rows. Laterally the markings are heavier and may form variously shaped figures. The underparts are yellowish or slightly tinged with dark and may even be somewhat mottled with brownish-black dots.

In the female, the lower valves of the ovipositor are approximately straight across the hind margin, being only very slightly rounded (Plate 14). The upper valves are about one-half to three-fifths as long as the cerci.

In the male, the subgenital plate, two-fifths as long as cerci and forming laterally two rounded lobes which extend posteriorly (Plate 15).

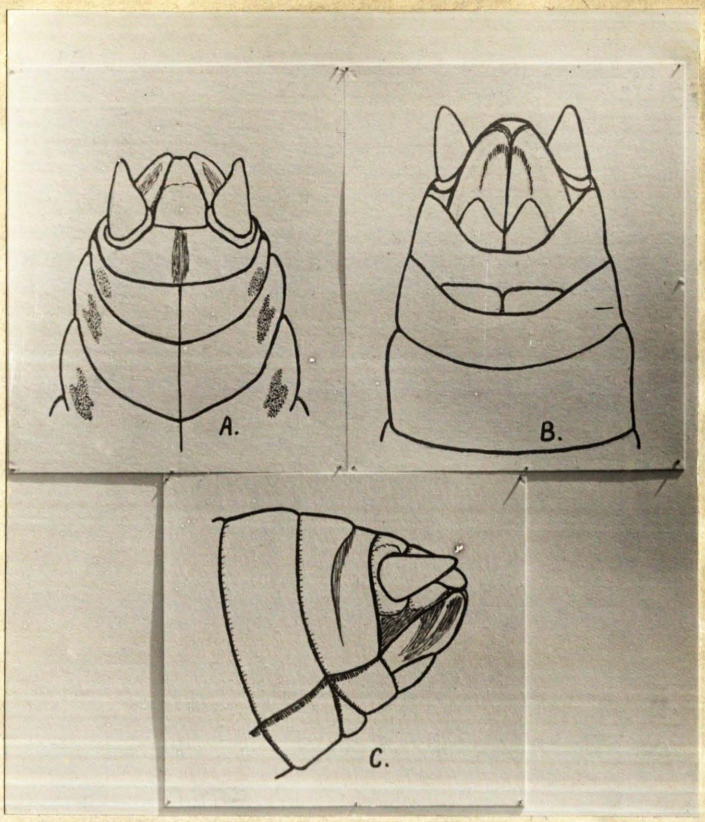

Plate 14. Posterior end of abdomen of first instar M. bivittatus female. A, dorsal view; B, ventral view; C, lateral view.

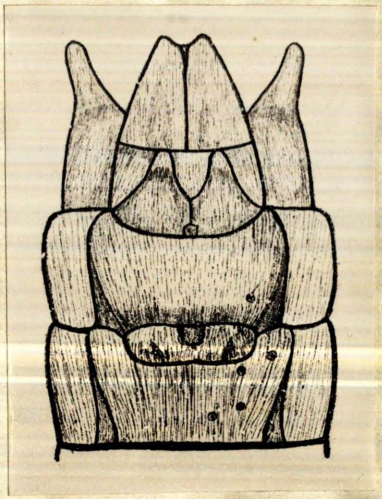

Plate 14'. First instar M. bivittatus female. Ventral view of posterior end of abdomen.

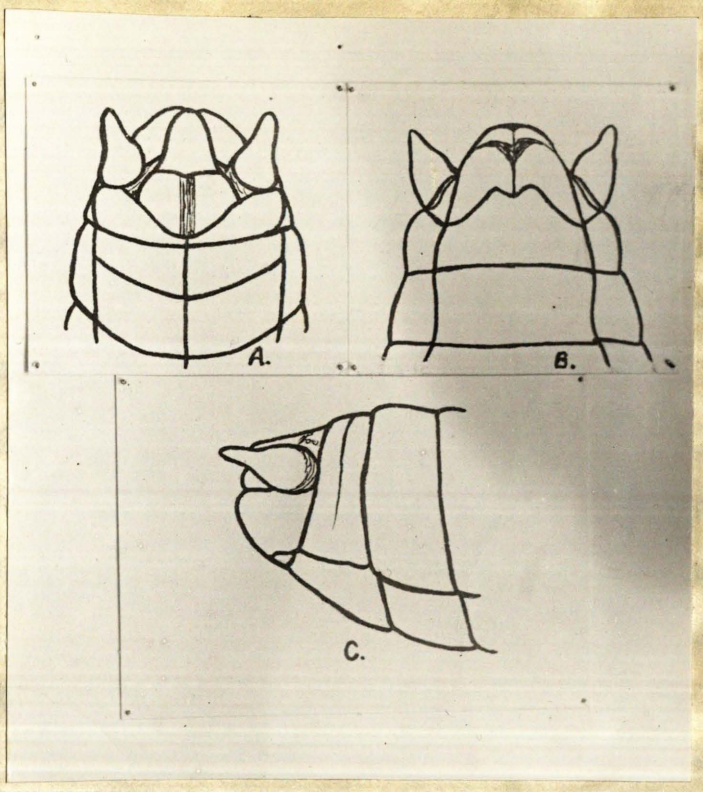

Plate 15. Posterior end of abdomen of first instar M. differentialis male. A, dorsal view; B, ventral view; C, lateral view.

Second Instar M. differentialis

Length of Body - 5.5 to 9.9 mm., depending on whether individual is near beginning or end of instar.

General Coloration - Same as for first instar. Markings of femora tend to become more sharply defined.

Head - Coloration same as for first instar. Cheeks and face dusky to fuscous. Frontal costa and disk of vertex concave. Antennal segments 15 to 17; large majority 17 (Plate 7).

Thorax -

Prothorax - Median carina light to dark; raised, but not so sharp as in first instar. Lateral carinae absent. Coloration same as in first instar except that lateral line may be better developed and show a tendency to be somewhat tinged with brownish.

Mesothorax and Metathorax - Median carina light to dark; slightly raised. Tegminal pads usually not discernable as such, but occasionally very slightly swollen and bent posteriorly. Wing pads not discernable. Subrectangular, fuscous area present on metathorax at point which will later be the base of the wing pad. First and second pairs of legs yellowish sprinkled with dusky.

Hind Femur - Length, 3.1 to 3.9 mm., majority 3.3 to 3.7 mm. Outer face of upperparts above chevrons with three distinct dark areas alternating with light areas (Plates 4, 5, 24); occasionally, a fourth, much smaller dark area is present at the distal end of the femur. Outer underparts dark; inner underparts clear. Chevrons with dark of upper half to three-fifths not in a solid line but broken by areas of yellowish-white which correspond in position to the light areas of the outer face of the upperparts, thus giving somewhat of a transversely banded appearance to the femur (Plates 4, 5). The dark is continuous thru the vertices of the chevrons to the most distal light area of the upper halves. Posterior to this light area the chevrons are dark for their entire width. The lower half of the chevrons is yellowish-white.

Tibia dark above; lighter beneath; a dark basal band present, with light one just posterior to it. Spines fuscous to black.

Abdomen - Median carina raised or smooth; light to dusky. Coloration same as first instar.

In the female, upper valves of ovipositor definitely pointed posteriorly. Lower valves roundly pointed posteriorly; about three-fourths as long as upper valves (Plate 16).

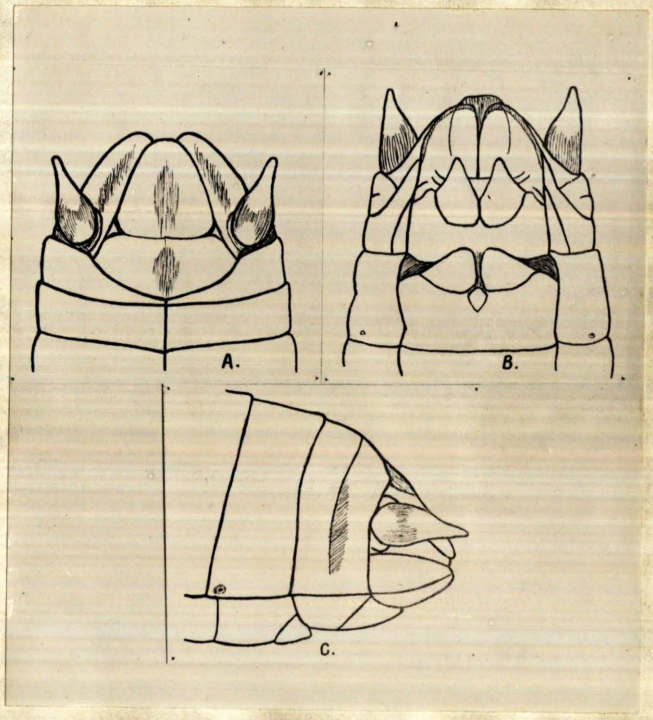

Plate 16. Posterior end of abdomen of second instar M. differentialis female. A, dorsal view; B, ventral view; C, lateral view.

In the male, subgenital plate definitely rounded and curved upward; about twice as long as cerci (Plate 17).

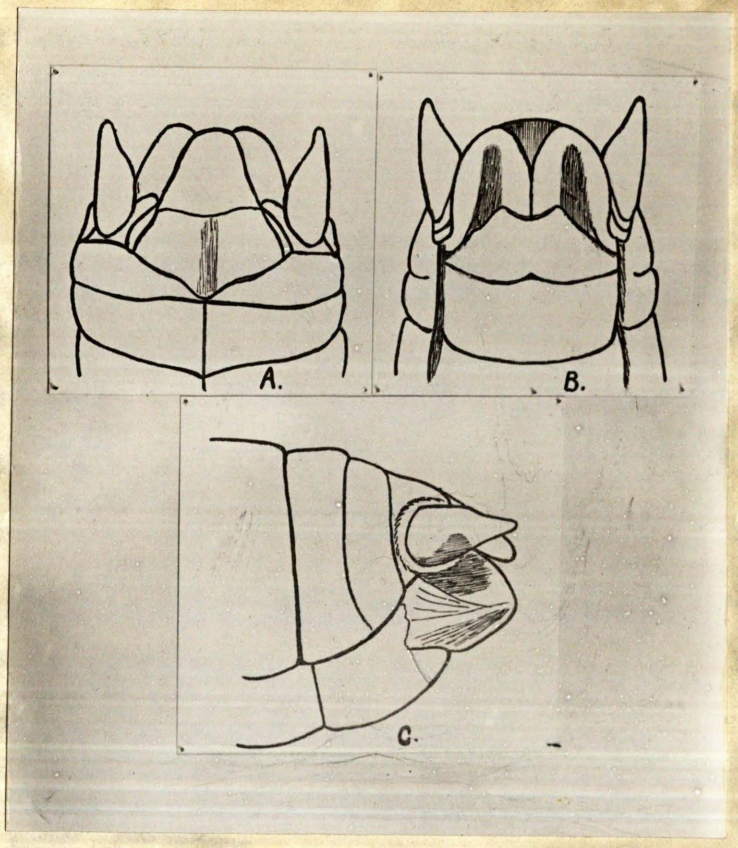

Plate 17. Posterior end of abdomen of second instar M. differentialis male. A, dorsal view; B, ventral view; C, lateral view.

Third Instar M. differentialis

Length of Body - 7.2 to 12.0 mm. depending on nearness to beginning or end of instar.

General Coloration - Same as for preceding instars except that light and dark areas usually show up brighter and are more clearly defined.

Head - Coloration same as for preceding stages. Frontal costa concave. Antennal segments 19 to 20, approximately 95% of nymphs with 20 (Plate 8).

Thorax -

Prothorax - Median carina raised but not knife-like; light colored. Median dorsal yellowish stripe narrow. Lateral yellowish stripe present but may not reach front and hind margins of pronotum; somewhat mottled; upper margin of stripe clearly defined and bordered above by fuscous to black which blends into the background color over disk of pronotum (Plate 18). Mottling persists to the base of the keel.

Plate 18. Pronotum, tegmina and wing pads of third instar M. differentialis.

Mesothorax and Metathorax - Median carina slightly raised; yellowish. Tegminal and wing pads definitely distinguishable, the former covering the base of the latter. Tegminal pads definitely pointing downward and backward; extension of wing pads not so pronounced (Plate 18). Anal venation of wing

pads slightly discernable. Such venation may or may not be apparent in pads of tegmina. Subrectangular dark area usually present at base of wing pads. First and second pairs of legs sprinkled with brownish above; clear below.

Hind Femur - Length 4.7 to 6.6 mm.; majority 4.7 to 5.4 mm. Outer face of upperparts marked with three distinct dark areas alternating with areas of yellowish (Plates 4, 5, 24). Outer underparts slightly shaded to dark; inner underparts clear. Chevrons with fuscous of upper one-half to three-fifths usually broken by light areas which correspond in position to the light areas of the upperparts giving somewhat of a banded appearance to the femur (Plates 4, 5). While this condition of the chevrons does not exist at all times, the fuscous being unbroken, the characteristic markings of the upperparts remain nevertheless.

Tibia dark above, light below; dark basal band present with light band immediately distal to it.

Abdomen - Median carina slightly raised; light colored. Coloration same as for preceding instars.

In the female, valves of ovipositor subequal in length; not quite as long as cerci. Two small lobes, the inner gonapophyses or inner valves of the ovipositor, may or may not be visible between and at the base of the upper valves (Plate 19).

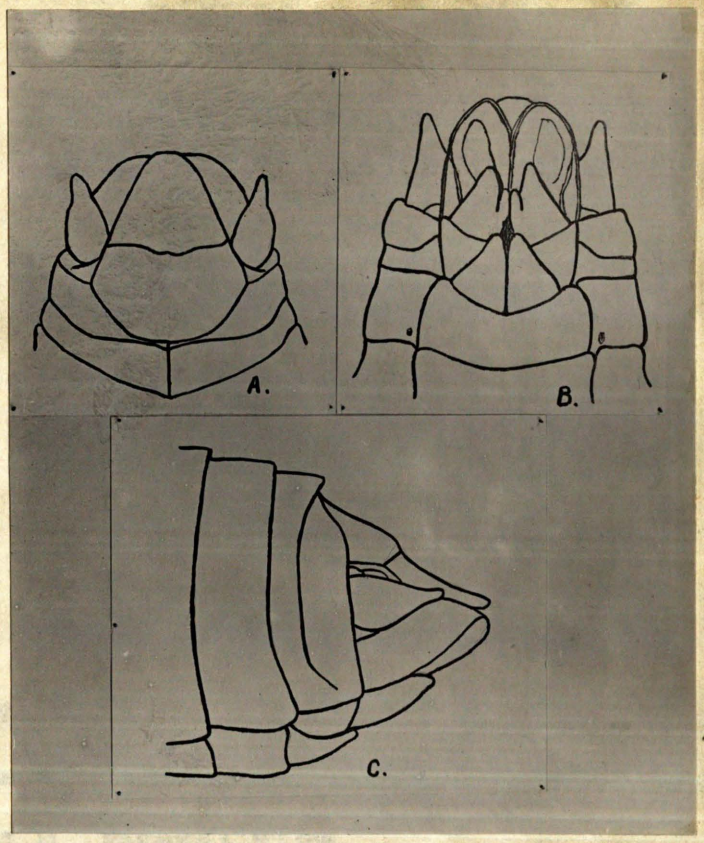

Plate 19. Posterior end of abdomen of third instar M. differentialis female. A, dorsal view; B, ventral view; C, lateral view.

In the male, subgenital plate definitely rounded and curved upward; truncate with hind angles obtuse (Plate 20).

Fourth Instar M. differentialis

Length of Body - 12.0 to 13.9 mm., may be slightly more or less, depending on nearness to beginning or end of instar.

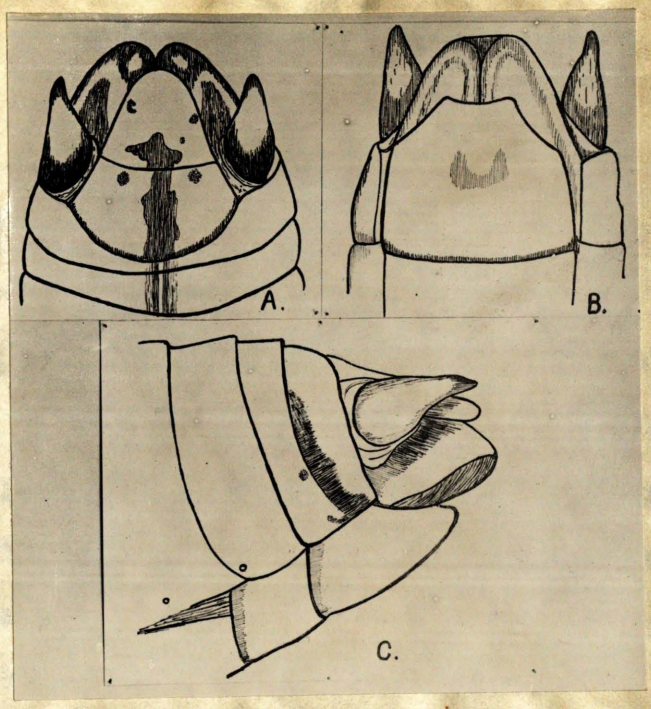

Plate 20. Posterior end of abdomen of third instar M. differentialis male. A, dorsal view; B, ventral vew; C, lateral view.

General Coloration - Same as for preceding instars. Some individuals may take on a more mottled or "peppered" appearance. In melanistic individuals the characteristic yellowish-white markings showing tendency toward band formation around femur and proximal end of tibia; bands show clearly against the dark background.

Head - Coloration same as for preceding instars. Frontal costa concave; fastigium slightly convex; disk of vertex slightly concave. Antennal segments 22 to 23 (Plate 8).

Thorax -

Prothorax - Median carina somewhat raised, not sharp, light to dark in color. Lateral carinae absent. Coloration same as for preceding instars.

Mesothorax and Metathorax - Median carina slightly raised, light colored. Coloration of tergites same as for preceding instars. Wing pads point downward, those of tegmina overlapping those of wings (Plates 9, 29). Indications of venation usually plainly visible. First and second pairs of legs sprinkled with brownish above, clear below.

Hind Femur - Length, 6.7 to 8.0 mm.; majority 6.7 to 7.5 mm. Coloration same as for preceding instars.

Tibia same as for preceding instars. Knees light to dusky, lower outer lobes lightly mottled.

Abdomen - Coloration same as for preceding instars.

In the female, lower valves of ovipositor and cerci subequal in length; cerci pointed. Inner gonapophyses of ovipositor may be visible above the lower valves or entirely covered by them, depending upon the amount of food in the abdomen or the nearness to the beginning or end of the instar (Plate 30).

In the male, cerci fuscous-tipped, very slightly flattened laterally. Subgenital plate definitely curved upward, truncate; hind angles obtuse. Plate extends about three-fourths the length of the paraprocts. The anal plate is triangular in shape with a rounded apex (Plate 21).

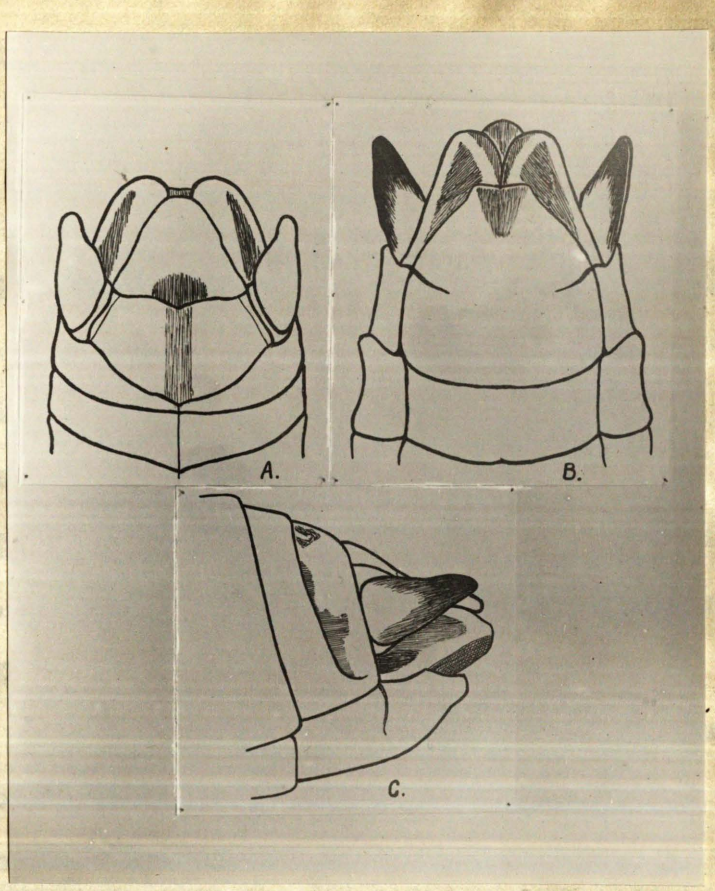

Plate 21. Posterior end of abdomen of fourth instar M. differentialis male. A, dorsal view; B, ventral view; C, lateral view.

Fifth Instar M. differentialis

Length of Body - 13 to 20.5 mm., depending upon the extent to which the body is distended.

General Coloration - Same as for preceding instars.

Head - Coloration same as for preceding instars. Frontal costa concave; fastigium slightly convex; disk of pronotum shallowly

concave to slightly convex. Antennal segments, 23 to 26; 90% to 95% of specimens with 24 or 25.

Thorax -

Prothorax - Median carina light to dark, slightly raised but not sharp. Lateral carinae absent; pronotum evenly rounded, without definite lateral angles. Coloration same as for preceding instars.

Mesothorax and Metathorax - Median carina slightly raised, light colored. Coloration of tergites same as for preceding instars. Wing pads point upward, the pads of the wings overlapping those of the tegmina (Plates 10, 11). The length of a wing pad from the apex to the anterior point of the base, is one-half to three-fifths the length of the median carina of the pronotum. The pads are usually fuscous to black with the costal and apical margins whitish, the former being two to three times as wide as the latter. The fuscous of wing, especially in the cubito-anal region, is usually cut into sectors by whitish lines extending from the base to the margin of the pads, the lines apparently being the paths followed by the principal veins. Occasionally the light lines between the fuscous sectors are wider than the sectors themselves and may even have broken fuscous lines in them (Plate 13). In these cases the pads have more light color than fuscous over their surfaces. The light lines, and consequently the sectors, are not present in melanistic individuals, the entire expanded area of the wing pads being dark. In the majority of cases there is a small yellowish to yellowish-white area at the

base of the cubito-anal group of veins. This character usually persists even in melanistic specimens. The first and second pairs of legs are as in preceding instars.

Hind Femur - Length, 7 to 10.7 mm., majority 8.2 to 10.2 mm. Coloration same as for preceding instars. Color markings of tibia as in earlier stages.

Abdomen - Coloration same as for preceding instars.

In the female, upper and lower valves of ovipositor subequal in length and about as long as or slightly longer than the cerci. Inner gonapophyses of ovipositor may or may not be visible depending upon the extent to which the abdomen is distended. Upon raising or removing the lower valves, the inner valves are readily exposed. They are about as long as the lower valves (Plate 22).

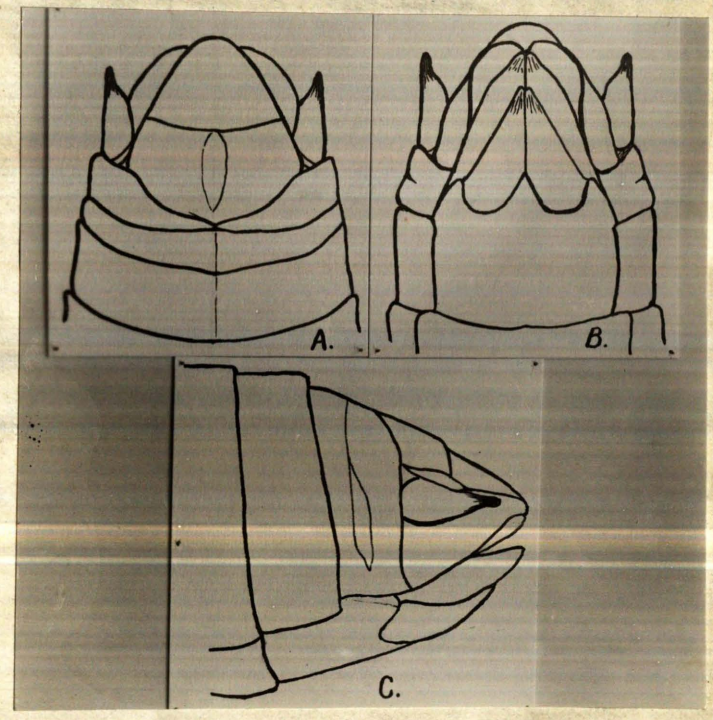

Plate 22. Posterior end of abdomen of fifth instar M. differentialis female. A, dorsal view; B, ventral view; C, lateral view.

In the male, the cerci are laterally flattened, more noticeably at the distal end, and are definitely assuming the "clasper" shape. Subgenital plate extends to the posterior end of the abdomen, is roundly pointed and has practically assumed its final or adult shape, except for growth. Anal plate triangular, tapering regularly to a rounded apex.

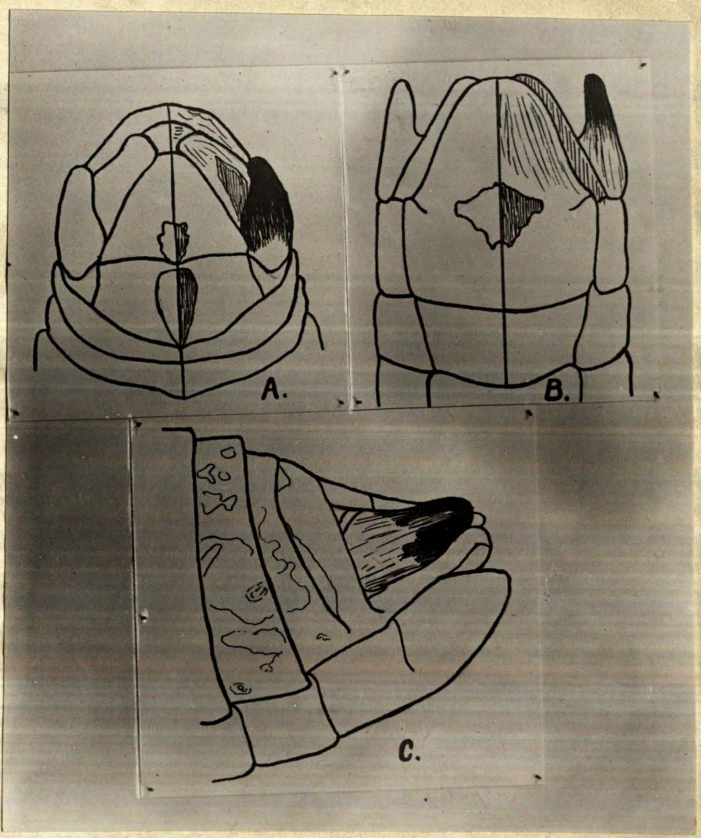

Plate 23. Posterior end of abdomen of fifth instar M. differentialis male. A, dorsal view; B, ventral view; C, lateral view.

Sixth Instar M. differentialis

Length of Body - 15.5 to 29.5 mm., depending upon degree of distension of the body.

General Coloration - Same as for preceding instars.

Head - Coloration same as for preceding stages. Frontal costa shallowly concave; fastigium and disk of vertex shallowly concave to slightly convex. Antennal segments, 25 to 27, majority with 25 or 26.

Thorax -

Prothorax - Median carina light to dark, slightly raised but not sharp. Lateral carinae absent; pronotum evenly rounded, without definite lateral angles. Coloration same as for preceding instars.

Mesothorax and Metathorax - Median carina slightly raised, light colored. Coloration of tergites same as for earlier stages. Wing pads point upward, the pads of the wings overlapping those of the tegmina (Plate 39). The length of the wing pad from the apex to the anterior point of the base is the same length or slightly longer than the median carina of the pronotum (Plates 12, 13). Coloration of pads same as for fifth instar. Color markings of first and second pairs of legs same as for earlier stages.

Hind Femur - Length, 10.8 to 13.5 mm. Coloration of femora and tibia same as for preceding instars (Plates 4, 5, 24).

Abdomen - Coloration same as for preceding instars.

In the female, upper and lower valves of ovipositor subequal in length. Upper valves definitely pointed and turned

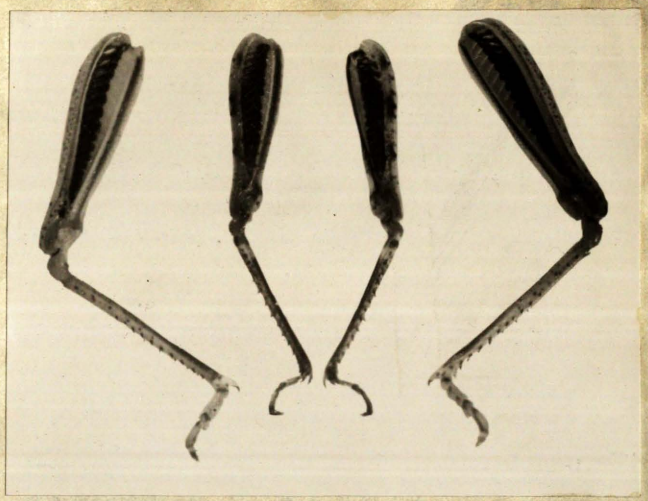

Plate 24. Hind legs of sixth instar nymphs. Outer figures, M. bivittatus; inner figures, M. differentialis.

upward, extending well back of paraprocts. Lower valves definitely pointed; a secondary point forming on the outer margin of each about two-fifths the distance from the proximal to the distal end (Plate 25).

In the male, cerci becoming definitely "boot-shaped", tipped with fuscous; more noticeably flattened distally. Subgenital plate differing from that of fifth instar only in size. Anal plate triangular, tapering to a rounded apex; margins not turned upward. (Plate 26).

Adult M. differentialis

Length of Body - 25.0 to 34.0 mm. Blatchley records 28 to 44 millimeters (1, p.440).

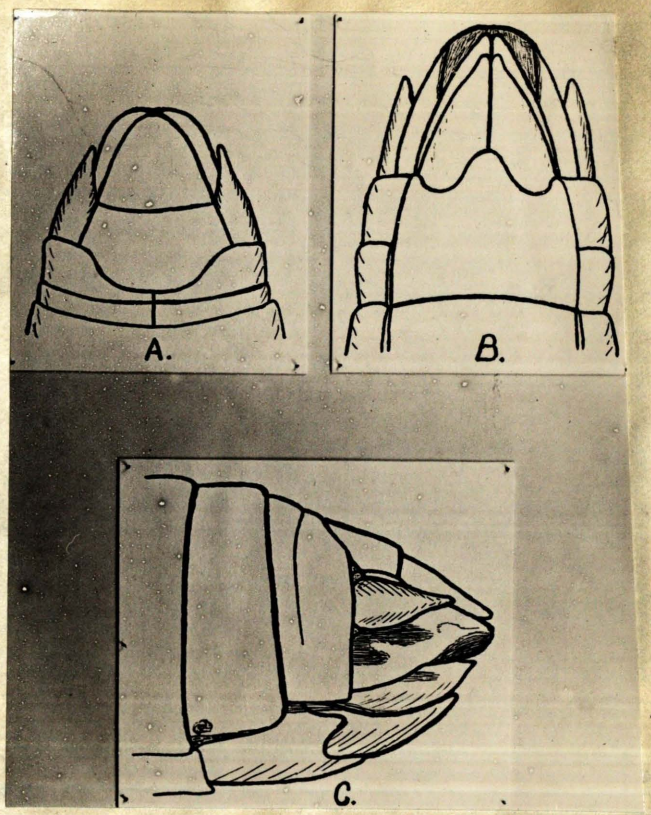

Plate 25. Posterior end of abdomen of sixth instar M. differentialis female. A, dorsal view; B, ventral view; C, lateral view.

General Coloration - Yellowish to yellowish green above, yellow beneath. Melanistic individuals grade from slightly darker colored to entirely black except for yellowish femoral markings.

Head - Yellowish to yellowish green or light olive. Frontal costa slightly concave, especially in region of median ocellus. Antennal segments, 27 to 29.

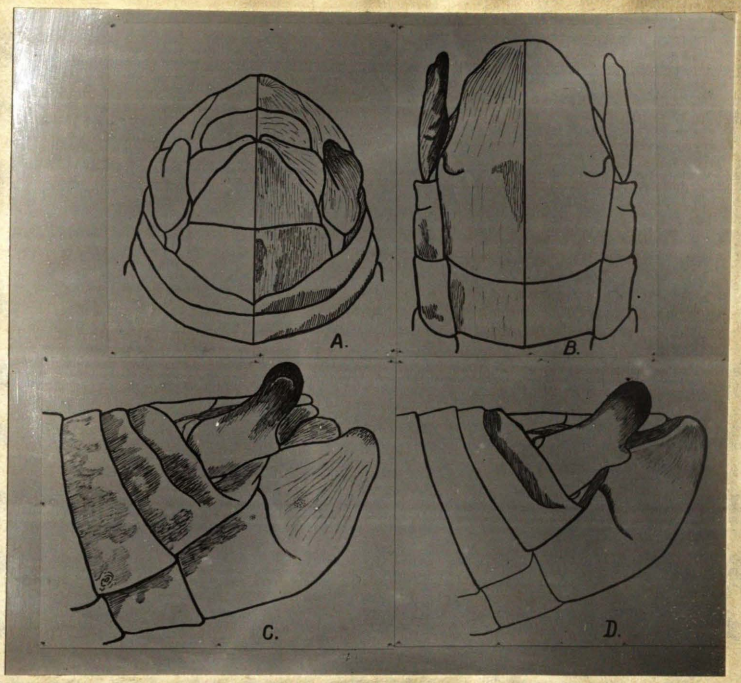

Plate 26. Posterior end of abdomen of sixth instar M. differentialis, male. A, dorsal view; B, ventral view; C,D, lateral views.

Thorax -

Prothorax - Median carina visible over entire length of pronotum, considerably sharper over metazona. Metazona rugose, prozona rather smooth. Sulcus separating prozona from metazona deeper than other sulci with a brownish black area adjacent to each side of the median carina. Lateral carinae present, obtuse angled, more pronounced over metazona. Disk of pronotum rather flat; hind angles slightly upturned. Lateral sulci black. Lateral lobes yellowish to greenish yellow or olive. The mottled markings of the nymphs have been lost in favor of the markings just described.

Mesothorax and Metathorax - Median carina visible when wings are spread. The wings are fully developed and approximate the tip of the abdomen. The wings are folded beneath the tegmina. First and second pairs of legs yellowish to yellowish-green above, yellow beneath.

Hind Femur - Length, 13 to 17.7 mm. Blatchley (1, p.440) states the length as 18.5 - 23 mm. Background yellow or showing varying degrees of melanism. Upperparts mottled with light brownish dots. The dark areas characteristic of the outer face of the upperparts of the femora of immature stages show very faintly or not at all in the adult. However, the dark areas show up very plainly over the inner face of the upperparts. Inner underparts clear yellow; outer underparts with a series of black dots or merely dark shading extending from the proximal to the distal end. The chevrons show a tendency toward band formation tho not so definitely as in nymphal stages. The dark upper halves of the chevrons do not run together as they did in the immature stages and usually the dark area of each chevron is separated from that of every other chevron by areas of yellow. The dark chevrons may or may not extend clear across the outer part of the femur. Those areas of the femur which are not fuscous to black are usually clear yellow. The knees are blackish with lower outer lobes yellowish.

The tibia has a blackish basal band. Remainder of tibia except spines usually yellow; spines black.

Abdomen - Median carina very slightly raised, not at all sharp.

Abdomen yellow beneath with black at lateral edges of sternites. Yellowish-green to brownish-yellow above, with variously shaped brownish-black to black areas laterally.

In the female, cerci short and stout, roundly pointed. Upper valves of ovipositor definitely upcurved, tips brownish to black, edges definitely toothed or crenulate, especially at the base. Lower valves definitely downcurved, tips brownish to black with a secondary point about half way down the exposed portion of the main valves. Slightly anterior to this is a second lobe to the valve. The sternite which forms the egg-guide also forms on each side a backward pointing structure with much the same appearance as the cerci.

The inner gonapophyses of the ovipositor appear as a forked organ at the base of and between the upper valves. According to Comstock and Kellog (3, p.29) it lies "dorsad of the egg-guide ... and also is used in placing the eggs."

In the male, the cerci or claspers are definitely boot-shaped, (Plate 28), and are usually tipped with fuscous. The subgenital plate is curved upward and terminates in a rounded tubercle which may be slightly incised but is usually smoothly rounded.

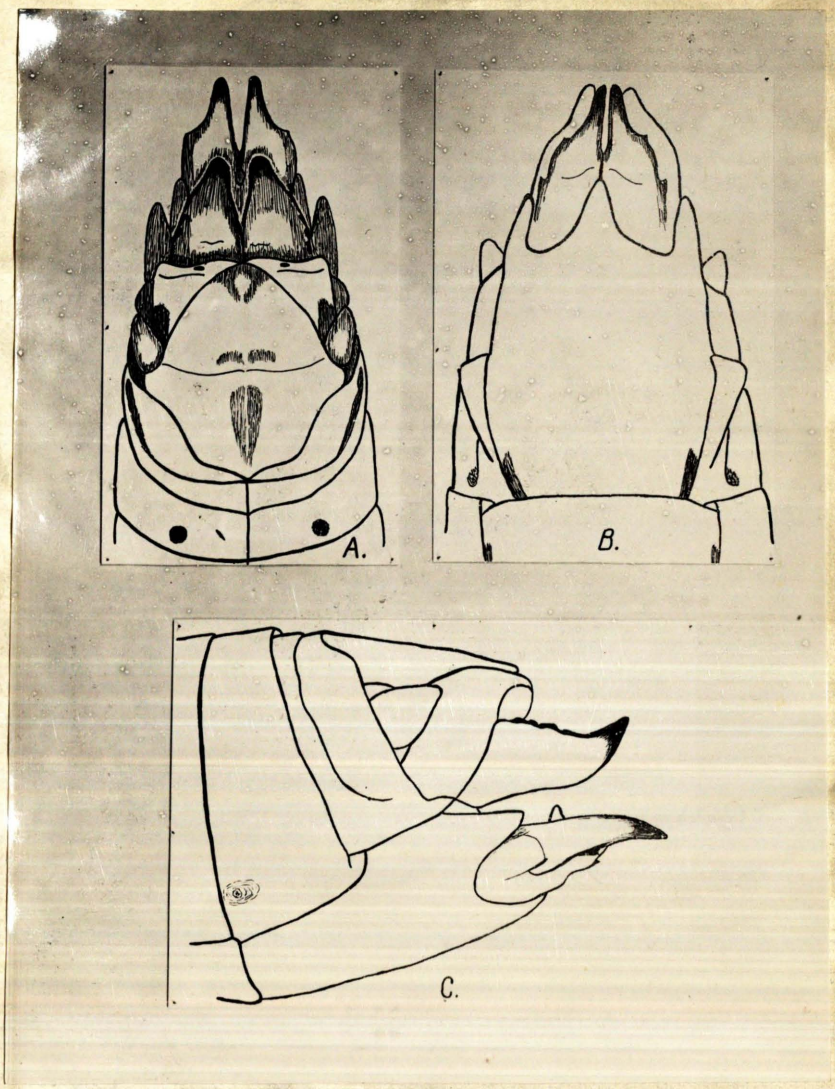

Plate 27. Posterior end of abdomen of adult M. differentialis female. A, dorsal view; B, ventral view; C, lateral view.

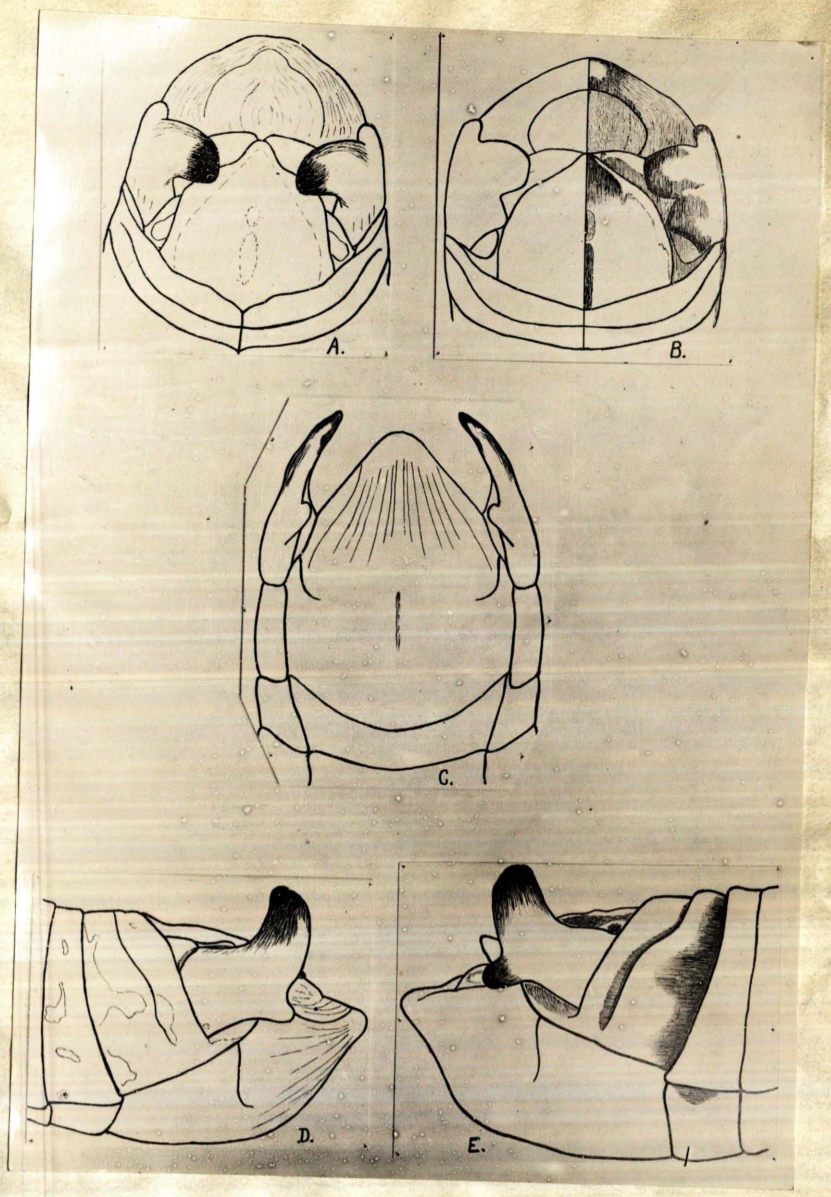

Plate 28. Posterior end of abdomen of adult M. differentialis male. A,B, dorsal views; C, ventral view; D,E, lateral views.

DESCRIPTION OF INSTARS OF M. BIVITTATUS

First Instar M. bivittatus

Length of Body - 4.0 to 7.1 mm., depending on degree of distension of body and nearness to beginning or end of instar.

General Coloration - Background color yellowish or yellowish-white to greenish-yellow mottled and tinged with fuscous to black.

Head - Yellowish-white or greenish-yellow mottled dorsally with patches of brownish-black. A yellowish stripe extends from the upper hind margin of the compound eye to the back of the head. This stripe is bounded ventrally by a fuscous area or stripe, the boundary between these two areas being sharp rather than blended. The median dorsal line is light colored and distinct. Mottling is heavier along each side of the line, the dark areas tending to elongate transversely, longer toward the back of the head, thus producing a triangle over the occiput, with its vertex between the compound eyes. The mottling is also heavier along the margins of the compound eyes. A stripe of more or less clear yellow is present between the triangle and the mottled margins of the eyes. Cheeks may be lightly or quite heavily mottled with dusky to fuscous. The frontal costa is deeply furrowed. Disk of vertex and fastigium concave. Antennal segments 12 to 13; 90% to 95% of all individuals examined having definitely 13 (Plate 7).

Thorax -

Prothorax - Median carina light colored and sharply raised; knife-like. Lateral carinae absent. A lateral stripe, wider anteriorly, extends from the front to the hind margin (Plate 6). This stripe is sharply bounded above by a fuscous to black stripe which blends into the yellowish background color as it approaches the median carina. Usually the area on each side of the median carina is clear yellowish. The yellowish lateral line is bounded ventrally by either heavily mottled and tinged or very slightly mottled lateral lobes. Occasionally the pronotum may be almost entirely free from dark markings.

Mesothorax and Metathorax - Median carina light colored and raised; not so sharp as on pronotum. Wing pads not discernable as such. A subrectangular, fuscous area is present on the metanotum at a point which will later be the base of the wing pad (Plate 6). The yellow lateral stripe of the prothorax persists over the mesothorax with borders very similar to those of the prothoracic stripe. The first and second pairs of legs are yellowish to greenish-yellow, lightly mottled above with brownish.

The tibia are lightly mottled above, clear between spines.

Hind Femur - Length, 2.2 to 2.9 mm.; majority 2.3 to 2.7 mm. Outer face of upperparts usually of a clear yellowish to yellowish-white, sometimes very lightly flecked with brownish. Occasionally there is a tendency to show three slightly darker areas on the outer face. These are always present on the inner surface. Lower parts with inner face clear and outer face

grading from clear to dark fuscous. Outer face of femur has appearance of "chevrons" or "herring-bone" weave. The upper half of the chevrons is solid fuscous to black, except occasionally the extreme upper ends of the proximal two or three chevrons and fine lines separating them which may be yellowish to yellowish-white. The lower part of the chevrons, except at the distal end of the femur, is clear yellowish or yellowish-white (Plates 1, 2, 3, 24).

Tibia lighter toward proximal end, darker toward distal end.

Abdomen - Median carina light colored; slightly raised earlier in the instar, more rounded out later in the stage. Bordered by yellowish, forming broader yellowish dorsal stripe than over thorax. Lightly flecked with brownish above, the dots tending to form longitudinal rows. Laterally the abdomen is much more heavily mottled and tinged, with variously shaped areas at the lower margins of the tergites. The anal plate has a mid-dorsal, rather broad line of brownish-black.

In the female, the lower valves of the ovipositor are approximately straight across; slightly rounded posteriorly. Upper valves about one-half to three-fifths as long as cerci (Plates 14 & 14').

In the male, subgenital plate process about two-fifths as long as cerci (Plate 15).

Second Instar M. bivittatus

Length of Body - 6.0 to 8.6 mm.

General Coloration - Yellowish background mottled and shaded with fuscous to black. In some cases the yellowish color has a slight tinge of green.

Head - Coloration same as for first instar. Frontal costa concave. Antennal segments 17 to 19; majority 17, quite often 18, rarely 19 (Plate 7).

Thorax -

Prothorax - Median carina distinctly raised tho not so sharp as to be termed knife-like; light colored. Lateral carinae absent. Color markings as in first instar, with general coloration as indicated above.

Mesothorax and Metathorax - Median carina slightly raised and light colored. Light lateral line of pronotum persists over mesonotum and metanotum as do the darker areas bordering it. The dark areas may, however, be lacking in some cases. In others they may extend over the remainder of the two segments. Color markings usually the same as for first instar.

Hind Femur - Length, 3.4 to 3.7 mm. Color markings same as for first instar. Markings of chevrons usually stand out more sharply than in first instar.

Tibia dark above, light below; spines fuscous.

Abdomen - Coloration same as in first instar. In the female, the upper valves of the ovipositor have become definitely pointed structures while the lower valves are still somewhat rounded at the distal ends tho they definitely point posteriorly. The lower valves are about 1/2 as long as the cerci, or about 3/5 to 4/5 as long as the upper valves (Plate 16).

In the male, the cerci are pointed; subgenital plate somewhat rounded and curved upward. Hind margin of plate truncate with lateral angles obtuse. (Plate 17).

Third Instar M. bivittatus

Length of Body - 7.3 to 12.0 mm., depending on nearness to beginning or end of instar.

General Coloration - Same as preceding instars, except that some individuals exhibit a definite green background rather than the usual yellowish color. Dark markings usually clearly defined. All colors brighter or more definite.

Head - Coloration same as for preceding instars. Frontal ridge concave. Antennal segments, 19 to 21, approximately 95% with 20 (Plate 8).

Thorax -

Prothorax - Median carina raised but not knife-like; light colored. Lateral carinae absent. Coloration same as for preceding instars.

Mesothorax and Metathorax - Median carina slightly raised; yellowish to green. Yellow or green and fuscous stripes of pronotum persist over mesonotum and metanotum. Coloration in general same as for preceding instars. Tegminal and wing pads definitely distinguishable. Tegminal pads slightly more extended downward and backward than wing pads, the former covering anterior part of the latter (Plates 9, 13). Slight indication of anal venation in wing pad, occasionally in tegminal pad. Coloration of first and second pairs of legs same as for preceding instars.

Hind Femur - Length, 5.0 to 5.7 mm. Outer face of upperparts above chevrons yellowish to green; clear or lightly sprinkled with brownish; occasionally marked with three very faintly darker areas. Chevrons solid blackish over the upper one-half or three-fifths, except possibly for extreme upper ends of proximal two or three chevrons and fine lines separating them. These exceptions and the lower two-fifths to one-half of the chevrons are of clear background color. The distal two or three chevrons are usually entirely fuscous to black, even over the lower part. Coloration in general same as for preceding instars.

Tibia with upperparts dark, laterally sprinkled with brownish to black and underparts, between spines, clear background color.

Abdomen - Median carina slightly raised; light colored. Tergites rather heavily to lightly shaded. Markings as in pre-

ceding stages. Sternites of background color clear to lightly tinged with brownish.

In the female, valves of ovipositor subequal in length, not quite as long (3/5 to 4/5) as cerci. Two small lobes, the inner gonapophyses or inner valves of ovipositor, visible between and at the base of the upper valves (Plate 19).

In the male, cerci pointed. Subgenital plate definitely rounded and curved upward, truncate with hind angles obtuse. Plate does not quite reach the ends of the paraprocts (Plate 20).

Fourth Instar M. bivittatus

Length of Body - 10.6 to 16 mm. depending upon amount of food in the body and nearness to beginning or end of instar.

General Coloration - Same as for preceding instars.

Head - Coloration same as for preceding instars. Frontal costa concave; fastigium slightly convex; disk of vertex shallowly concave. Antennal segments 22 to 23 (Plate 8).

Thorax -

Prothorax - Median carina light colored, somewhat raised but not sharp. Lateral carinae absent. Coloration same as for preceding instars.

Mesothorax and Metathorax - Median carina slightly raised, light colored. Coloration of tergites same as for preceding

instars. Wing pads point downward, those of tegmina overlapping those of wings (Plates 9, 29). Indications of venation usually

Plate 29. Wing and tegmina pads, and pronotum of fourth exuvium of M. bivittatus.

plainly visible. Pads of both tegmina and wings may be margined with whitish. Anal region of wings may be cut into sectors by fine whitish lines. First and second pairs of legs clear below, sprinkled lightly with brownish above.

Hind Femur - Length 6.7 to 7.6 mm. Coloration same as for preceding instars.

Tibia same as for preceding instars.

Abdomen - Coloration same as for preceding instars.

In the female, lower valves of ovipositor and cerci are subequal in length; cerci pointed. Inner gonapophyses of ovipositor may be visible above the lower valves or entirely

covered by them depending upon the degree of distension of the abdomen (Plate 30).

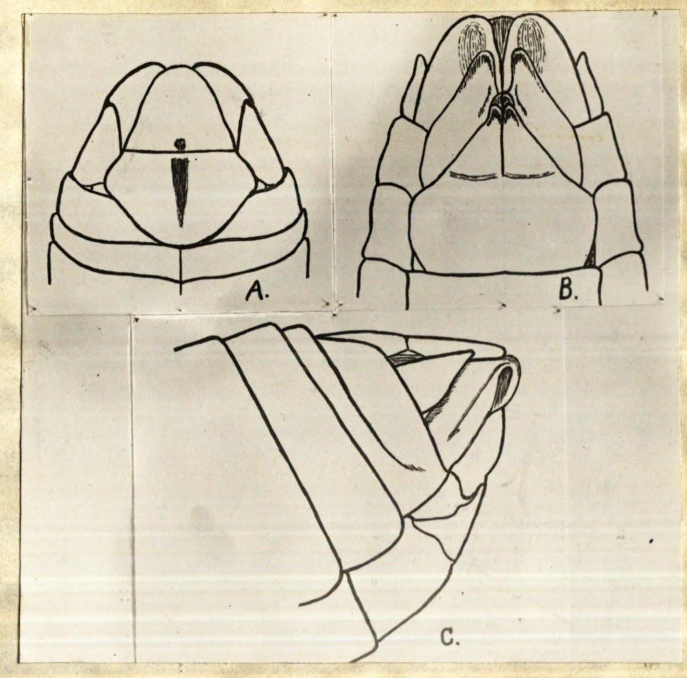

Plate 30. Posterior end of abdomen of fourth instar M. bivittatus. A, dorsal view; B, ventral view; C, lateral view.

In the male, cerci fuscous-tipped, very slightly flattened laterally. Subgenital plate truncate and definitely curved upward; hind angles obtuse. Plate extends about three-fourths the length of the paraprocts. Anal plate triangular with rounded apex (Plate 21).

Fifth Instar M. bivittatus

Length of Body - 13 to 19 mm., depending on degree to which the body is distended, with food or otherwise.

General Coloration - Same as for preceding instars. In green individuals the color is somewhat lighter than in earlier stages.

Head - Coloration same as for preceding instars. Frontal costa concave; fastigium slightly convex; disk of vertex

shallowly concave to slightly convex. Antennal segments 23 to 25; 90% to 95% of specimens with 24 or 25.

Thorax -

Prothorax - Median carina light colored, slightly raised but not sharp. Lateral carinae absent; pronotum evenly rounded, without definite lateral angles. Coloration same as for preceding instars.

Mesothorax and Metathorax - Median carina slightly raised, light colored. Coloration of tergites same as for preceding instars. Wing pads point upward, the pads of the wings overlapping those of the tegmina. The length of the wing pad from the apex to the anterior point of the base, is one-half to three-fifths the length of the median carina of the pronotum (Plates 10, 11). The pads are usually fuscous to black with the costal and apical margins whitish, the former being two to three times as wide as the latter (Plate 31). The area of the wing covered by the cubito-anal group of veins is sometimes cut into sectors by whitish lines extending from the base to the margin of the pad. This area may, however, be entirely fuscous. First and second pairs of legs sprinkled with brownish above, clear below.

Hind Femur - Length, 7.3 to 10.0 mm., majority 7.3 to 8.9 mm. Coloration same as for preceding instars.

Color markings of tibia same as for earlier stages.

Abdomen - Coloration same as for preceding instars.

In the female, upper and lower valves of ovipositor

subequal in length and about as long as or slightly longer than cerci. Inner gonapophyses of ovipositor may or may not be visible, depending upon the extent to which the abdomen is distended. Upon raising or removing the lower valves the inner valves are readily exposed. They are about as long as the lower valves (Plate 32).

In the male, the cerci are laterally flattened, more noticeably at the distal end, and are definitely assuming the "clasper" shape. Subgenital plate extends to posterior end of abdomen, is roundly pointed and has practically assumed its final or adult shape, except for growth. Anal plate triangular, tapering regularly to a rounded apex (Plate 33).

Plate 31. Tegmina (top) and wing (bottom) pads of fifth instar M. bivittatus.

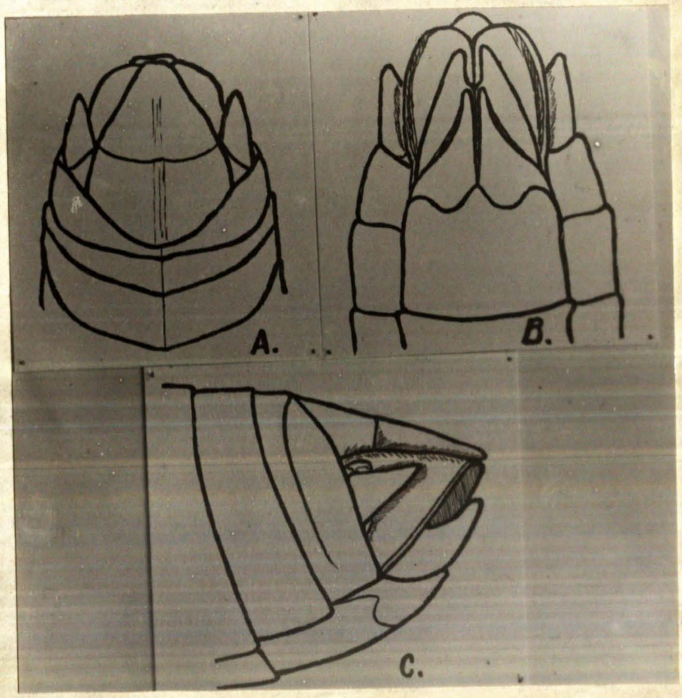

Plate 32. Posterior end of abdomen of fifth instar M. bivittatus female. A, dorsal view; B, ventral view; C, lateral view.

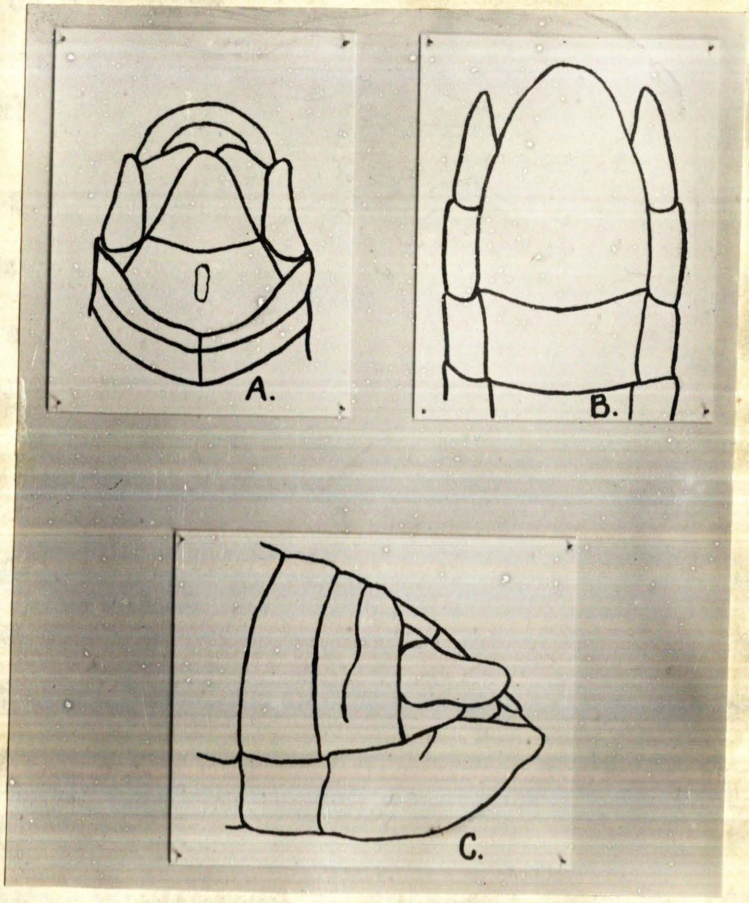

Plate 33. Posterior end of abdomen of fifth instar M. bivittatus male. A, dorsal view; B, ventral view; C, lateral view.

Sixth Instar M. bivittatus

Length of Body - 18.2 to 21.0 mm., depending upon degree of distension of the body.

General Coloration - Same as for preceding instars.

Head - Coloration same as for preceding stages. Frontal costa shallowly concave; fastigium and disk of vertex shallowly concave to slightly convex. Antennal segments, 25 to 28, majority with 25 to 27.

Thorax -

Prothorax - Median carina light colored, slightly raised but not sharp. Lateral carinae absent; pronotum evenly rounded, without definite lateral angles. Coloration same as for preceding instars.

Mesothorax and Metathorax - Median carina slightly raised, light colored. Coloration of tergites same as for earlier stages. Wing pads point upward, the pads of the wings overlapping those of the tegmina (Plate 39). The length of the wing pad from the apex to the anterior point of the base is the same or is slightly longer than the median carina of the pronotum (Plates 12, 13, 34, 39). Coloration of pads same as for fifth instar. Color markings of first and second pairs of legs same as for earlier stages.

Hind Femur - Length, 10.3 to 13.7 mm. Coloration of femora and tibia same as for preceding instars.

Plate 34. Tegmina and wing pads and pronotum of a sixth instar M. bivittatus male.

Abdomen - Coloration same as for preceding instars.

In the female, upper and lower valves of ovipositor subequal in length. Upper valves definitely pointed and turned upward, extending well back of paraprocts. Lower valves definitely pointed; a secondary point forming on the outer margin of each valve, about two-fifths the distance from the proximal to the distal end (Plate 35).

In the male, cerci tipped with fuscous and definitely assuming the "clasper" shape, a slight protrusion or swelling on the lower, posterior margin. Subgenital plate differing from that of fifth instar only in size. Anal plate triangular, tapering to a rounded apex; margins not turned upward (Plate 36).

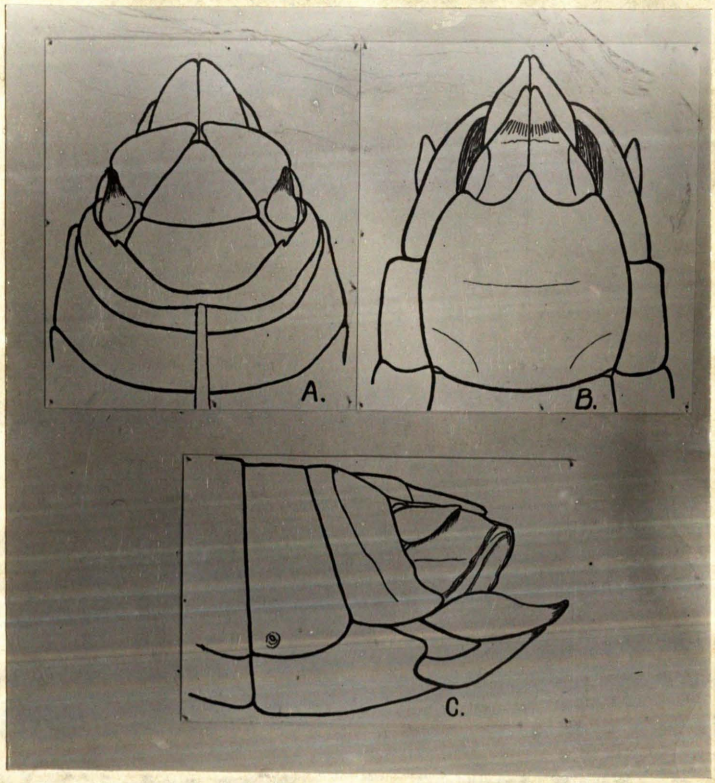

Plate 35. Posterior end of abdomen of sixth instar M. bivittatus female. A, dorsal view; B, ventral view; C, lateral view.

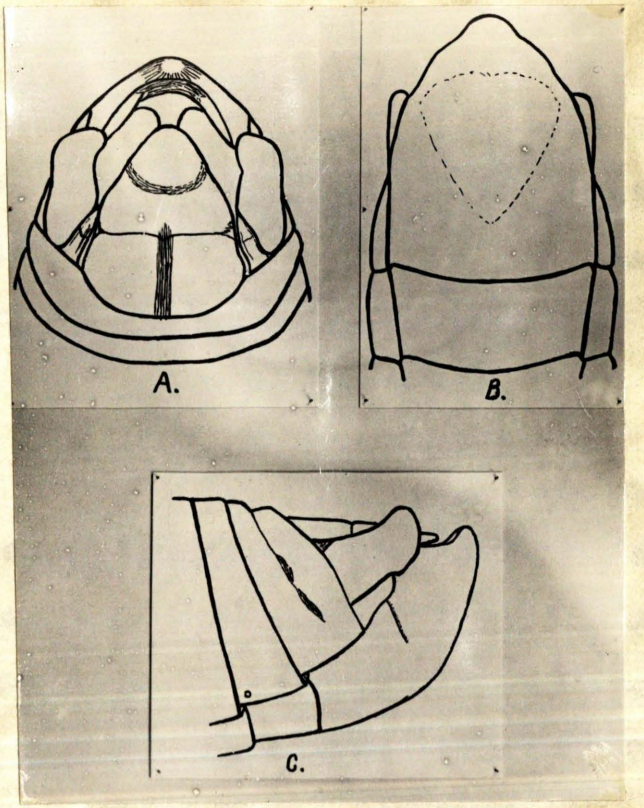

Plate 36. Posterior end of abdomen of sixth instar M. bivittatus male. A, dorsal view; B, ventral view; C, lateral view.

Adult M. bivittatus

Length of Body - 23 to 32 mm. Blatchley records this as 23 - 40 mm. (1, p.446).

General Coloration - Brownish-yellow to tan dorsally and laterally, lighter yellow ventrally. A yellow stripe extends posteriorly from the margin of each eye, along the lateral carinae of the pronotum and follows the wing out to a point

where the lines converge, at a point slightly anterior to the tips of the tegmina.

Head - Coloration same as for immature stages except that cheeks may show slight bluish tinge. Frontal costa slightly concave, especially in the region of the median ocellus. Antennal segments 27 to 29.

Thorax -

Prothorax - Median carina visible over entire length of pronotum, not so light colored as in earlier stages. Carina sharp over metazona; prozona smooth. Lateral carinae present. Metazona rugose; prozona smooth. Yellowish stripe as described above, bounded ventrally by fuscous. Disk of pronotum dusky to fuscous, nearly flat. Lateral lobes usually greenish yellow with tint of bluish. Sulci fuscous.

Mesothorax and Metathorax - Median carina visible when wings are spread. The wings are fully developed and approximate the tips of the abdomen. The yellow stripe of the head and pronotum extends along the angle of the tegmina almost to their tips, at least as far as the flattened upper surfaces extend. The wings are folded beneath the tegmina. First and second pairs of legs yellowish, darker above than beneath.

Hind Femur - Length, 10 to 16 mm. Blatchley (1, p.446) states the length as 13 to 22 mm. Coloration same as for immature stages. Yellowish background color may be much brighter but markings do not change.

Abdomen - Median carina very slightly raised, not at all sharp. Yellowish-green to brownish yellow above, brighter yellow beneath. Variously shaped fuscous areas laterally.

In the female, cerci short and stout, roundly pointed. The upper valves of the ovipositor are fuscous-tipped and curved upward, with the edges toothed or crenulate, especially at the base. The lower valves are also fuscous-tipped, curved downward and with a secondary point about half way down the exposed portion of the main valves. Slightly anterior to this is a second lobe to the valve. The sternite which forms the egg guide also forms on each side a backward painting structure with somewhat the appearance of a cercus but it is not as elongate as the corresponding structure in the female of M. differentialis (Plate 37).

The inner gonopophyses of the ovipositor appear at the base of and between the upper valves, as a forked organ, which, according to Comstock and Kellogg (3, p.29) lies "dorsad of the egg-guide ... and also is used in placing the eggs."

In the male, the cerci are somewhat "boot-shaped" but with the "sole of the boot strongly convex". The supra-anal plate is more or less triangular with the edges curved upward. The median sulcus of the plate is quite deep and narrow. The supra-anal plate is rather abruptly narrowed and incised near the apex. The subgenital plate (Sternite No. 10) is short, rather narrow and terminates in a rounded tubercle. The furcula is composed of a pair of short,

triangular lobes separated by a distance subequal to the width of the median sulcus of the supra-anal plate (Plate 38).

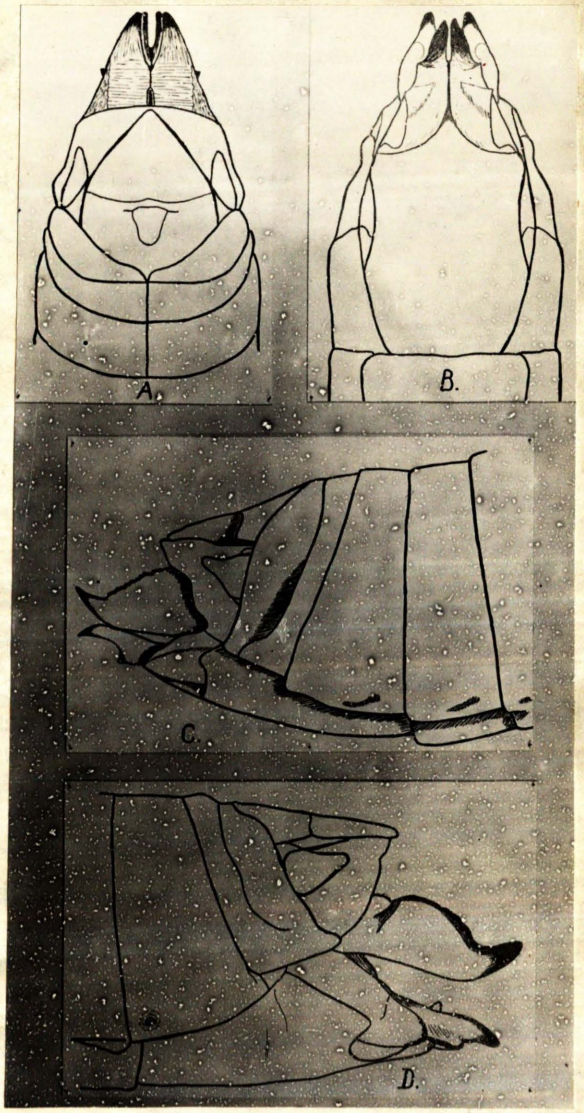

Plate 37. Posterior end of abdomen of adult M. bivittatus female. A, dorsal view; B, ventral view; C,D, lateral views.

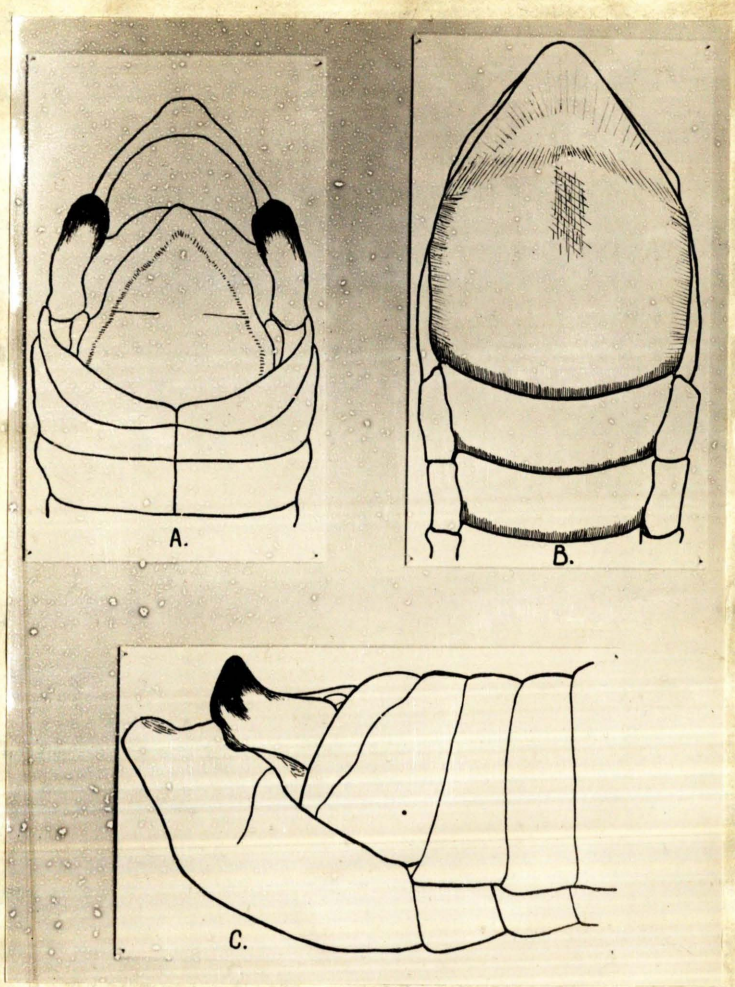

Plate 38. Posterior end of abdomen of adult M. bivittatus male. A, dorsal view; B, ventral view; C, lateral view.

Extra Instar

Ordinarily the grasshoppers in question undergo six molts, passing into the seventh stage as adults. These are called 6-instar hoppers. Occasionally, however, the nymphs pass thru an extra instar, that is, molt seven times, thus

becoming 7-instar hoppers, the adult stage being the eighth stage. These individuals may be either males or females but are most frequently the latter.

Shotwell (6), in his work with M. atlanis, in which 5-instar and 6-instar individuals are produced, places the extra molt between the third and fourth instars. He states that the "wing pads are turned upward in the last two instars before reaching maturity. This applies to all species of grasshoppers so far as is known." In the present study the author also found the wing pads to be turned upward in the last two nymphal instars, in the case of every individual raised thru to the adult stage (Plates 39, 40, 41, 42). Theoretically, then, if the specimen goes thru the extra instar, it should occur sometime before the regular fifth instar, that is, before the wings turn upward.

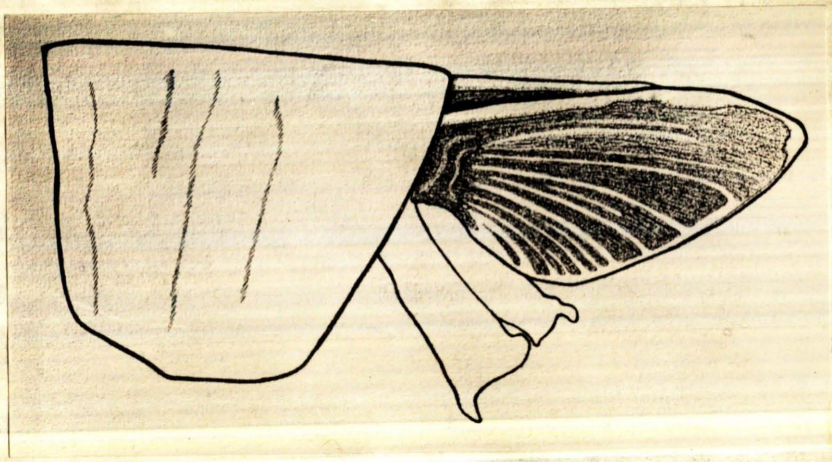

Plate 39. Pronotum and tegmina and wing pads of sixth instar M. bivittatus male. Contrast with plate 40 in wing development.

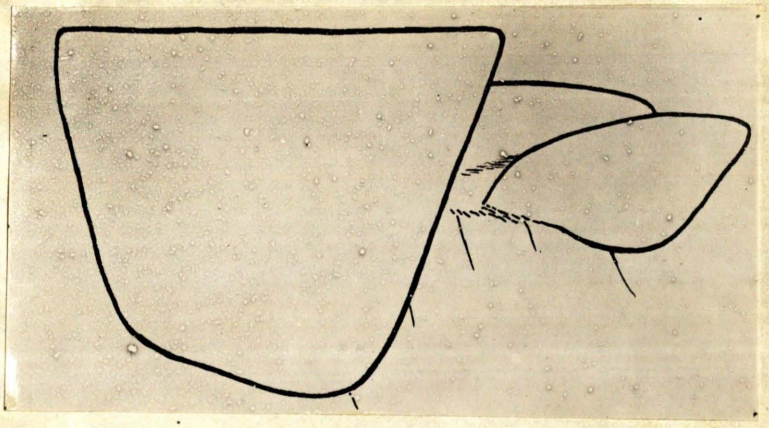

Plate 40. Pronotum and tegmina and wing pads of sixth instar M. bivittatus female, apparently a 7-instar hopper. Contrast with plate 39 in wing development.

In the last two stages before maturity, regardless of whether the individuals are 6-instar or 7-instar hoppers, there is so very little difference structurally that classificatory evidence, by means of which extra-instar nymphs can be separated from those with the normal number, cannot be based on morphological characters. There may be a difference in size but size alone cannot be used with any appreciable degree of accuracy in classifying grasshoppers nymphs to their instars.

Within their respective sexes, the nymphs of the first instar are all so similar structurally that it seems reasonably certain that the extra instar cannot immediately follow the intermediate molt. The same may be said of second and third instar nymphs with regards to the second and third molts respectively. In the instars preceding the upward

turning of the wing pads all the individuals within their respective sexes are so nearly alike that so far as the author has been able to ascertain, it is impossible to distinguish between the fourth instar of 6-instar hoppers and the fifth instar of 7-instar hoppers (Plates 39, 40, 41, 42). Size may possibly be used to a certain extent, but, as was mentioned before, is a poor criterion.

It seems logical, then to conclude that when the extra instar occurs the fourth or fifth molt is the "extra" mold and consequently the fourth or fifth instar the "extra" instar (Plate 11).

Due to the lack of sufficient data concerning this particular question it is impossible for the writer to do much more than theorize concerning the location of the extra instar. However, the evidence at hand seems to justify the conclusions drawn.

More detailed study of this phase of the problem would undoubtedly lead to the definite location of the extra instar and quite possibly to definite characterization of the stage. It is the writer's opinion that further study of the antennal segments, wing pads and length of hind femora, will give the necessary information.

For the reasons stated above and because of the very slight, if any, decrease in actual serviceability of the accompanying key by the omission of the extra instar, the latter has been disregarded in the building of the key.

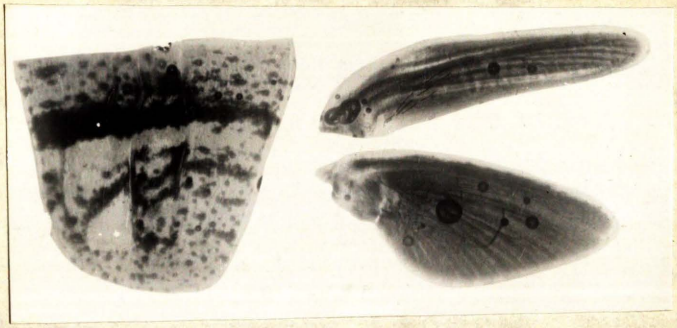

Plate 41. Pronotum and tegmina and wing pads of sixth instar M. bivittatus male. Contrast with plate 42 in wing development.

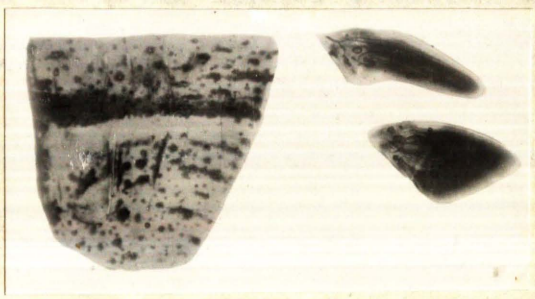

Plate 42. Pronotum and tegmina and wing pads of sixth instar M. bivittatus female. Contrast with plate 41 in wing development.

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